CHEMISTRY

JANUARY
1959

CHEMICAL ELEMENTS BEYOND PLUTONIUM N. C.

Authoritative History by
Discoverer Glenn Seaborg   Page 1

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The Ingredients of the Universe

➤ THIS IS A COMPLEX UNIVERSE in which we live, yet some aspects of it are simple as to numbers at least.

Take the chemical elements, the latest thrilling chapter of their discovery CHEMISTRY this month has the privilege of telling by reprinting Dr. Seaborg's important address. There are 102 known with no holes left in the periodic table, and we are confident that 118 will be reached in chemical elements to be discovered in the future.

Yet we must not be too dogmatic, because a couple decades ago, there were only three fundamental particles of the atom recognized, electron, proton and neutron, and now there are at least 24 so-called fundamentals, including the "strange" particles, and the end is not yet.

To put the units that make up the universe, or at least the earth, in perspective, there are believed to be 12,000 to 15,000 inorganic compounds known to the research chemist, and perhaps 500,000 organic compounds.

Of people on earth there are about 2,800,000,000 as of now (with world population increasing about 48,000,000 annually) and each of these individuals, exclusive of identical twins, is a unique combination of elements, molecules, etc.

Lower life is astoundingly more complex for there are probably well over a million species of insects known to science and of each species there are many million specimens.

The earth is presumably a unique planet, for none of the sun's family is like it, and man and the lesser life is alone in our own planetary system except perhaps for some very low forms of life, such as mosses, lichens or algae on Mars. There may be other worlds in the sphere of other stars, some 100,000,-000,000 of them in one galaxy, and there are billions of other galaxies within our telescopic reach and possibly trillions beyond our direct knowing.

But so far as we know, this vast universe is composed of the chemical elements we know or can expect to make.

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Recent Developments in the Field of

Transplutonium Elements

By Glenn T. Seaborg

The address given by Dr. Seaborg at the Second United Nations International Conference on the Peaceful Uses of Atomic Energy at Geneva contains so much valuable information not yet in books that **CHEMISTRY** is pleased to present this material. Dr. Seaborg is discoverer of many of the elements covered, Nobelist in chemistry in 1951, and director of the University of California's Radiation Laboratory until he became chancellor of the University of California at Berkeley last fall.

➤ I PLAN TO DESCRIBE some of the most interesting aspects of recent research on the synthetic transplutonium elements. The amount of recent information on these elements is obviously too much to cover completely in this brief presentation. I have, therefore, attempted to choose those topics which have the broadest implications for the whole transuranium field of research. Although much important and interesting research is, of course, being done in many laboratories, I have chosen examples mainly from the work in our own laboratory, the Radiation Laboratory at the University of California in Berkeley. I shall cover this information about the known transplutonium elements, list-

ed in Table I, by discussing them in

TABLE I
The Transplutonium Elements

95	Americium	Am
96	Curium	Cm
97	Berkelium	Bk
98	Californium	Cf
99	Einsteinium	E
100	Fermium	Fm
101	Mendelevium	Mv
102	—	—

order of increasing atomic number, and I shall conclude with some thoughts concerning the prospects for elements with higher atomic numbers than any that have been produced and identified up to the present time. For purposes of orientation, Figure I shows the position in the periodic

table of the presently known and the future transuranium elements. The transplutonium elements through element 103, together with the five preceding elements, are members of the "heavy rare earth," or actinide transition series, which is analogous to the lighter rare earth, or lanthanide, transition series. The undiscovered "trans-103" elements will fit into the periodic table as shown. I shall, of course, refer in this paper to the important unifying principle embodied in the periodic table.

FIGURE 1. *Position of the transuranium elements in the periodic table.*

Americium and Curium

Increasing amounts of the first two transplutonium elements, americium (atomic number 95) and curium (atomic number 96), are now becoming available for research in a number of laboratories even though the amounts are not nearly sufficient to meet the needs of the many impatient investigators. To date, most studies of americium and curium have been made using the isotopes Am^{241} and Cm^{242} and have been hampered by the high alpha radioactivity of these two isotopes. Of great importance, therefore, is the fact that useful amounts of the less radioactive Am^{243} and Cm^{244} and higher mass curium isotopes are now being produced. Their availability will greatly

facilitate chemical investigation of these elements.

Of particular interest is the determination of the electronic structure of the ground state of curium by J. C. Hubbs and co-workers, working with W. A. Nierenberg. They found that curium has an electronic structure exactly analogous to that of gadolinium, as was predicted on the basis of its position at the midpoint of the actinide series. With the completion of this experiment the electronic structures of the ground states of all the elements in the first half of the actinide series of elements are now known. The electronic configurations of these elements and their homologues in the lanthanide series are shown in Table II. It should be pointed out that these actinide elements

TABLE II

Known Electronic Structures of Actinide and Homologous Lanthanide Elements

89	Actinium	$6d7s^2$
90	Thorium	$6d^27s^2$
91	Protactinium	$5f^26d7s^2$
92	Uranium	$5f^36d7s^2$
93	Neptunium	$5f^46d7s^2$
94	Plutonium	$5f^67s^2$
95	Americium	$5f^77s^2$
96	Curium	$5f^76d7s^2$
57	Lanthanum	$5d6s^2$
58	Cerium	$4f^26s^2$
59	Praseodymium	$4f^36s^2$
60	Neodymium	$4f^46s^2$
61	Promethium	$4f^56s^2$
62	Samarium	$4f^66s^2$
63	Europium	$4f^76s^2$
64	Gadolinium	$4f^75d6s^2$

do not exhibit the pure Russell-Saunders (or L-S) type of coupling of their electrons as do the analogous lanthanide elements but the 5f and 6d electrons of the actinides are separately in Russell-Saunders coupling and are weakly coupled to each other.

Table III shows the predicted but as yet undetermined, electronic structures of the elements in the second half of the actinide group together with the known structures of the homologous lanthanide elements.

97	Berkelium	$5f^86d7s^2$
		or
		$5f^97s^2$
98	Californium	$5f^{10}7s^2$
99	Einsteinium	$5f^{11}7s^2$
100	Fermium	$5f^{12}7s^2$
101	Mendelevium	$5f^{13}7s^2$
102	102	$5f^{14}7s^2$
103	—	$5f^{14}6d7s^2$
65	Terbium	$4f^96s^2$
66	Dysprosium	$4f^{10}6s^2$
67	Holmium	$4f^{11}6s^2$
68	Erbium	$4f^{12}6s^2$
69	Thulium	$4f^{13}6s^2$
70	Ytterbium	$4f^{14}6s^2$
71	Lutetium	$4f^{14}5d6s^2$

The electronic configurations of curium and most of the preceding actinide elements have been determined through the study of the hyperfine structure of the free atoms by the atomic beam method. Figure 2 illustrates the basic elements of the method. A crucible is filled with the material under investigation and heated to 1000-3000°C to produce a beam of neutral atoms. This beam passes through a system of collimating and analyzing slits and three magnets, two of which, labelled A and B, produce deflecting fields. This system is arranged so that normally no atoms can reach the detector. If, however, an appropriate transition between magnetic substates in the atoms is induced in the homogeneous field produced by magnet C, a portion of the beam can reach the detector. Thus one can study the hyperfine structure of free atoms, which is a function of both electronic and nuclear structure. The hyperfine structure interaction involves predominantly the interaction of the nuclear magnetic dipole moment with the magnetic field at the nucleus arising from valence or unpaired electrons. The principal electronic information derived is the electronic angular momentum and Lande g-factor of all electronic states within several thousand cm⁻¹ of the ground state. This information, in combination with chemical, paramagnetic, optical and crystal structure
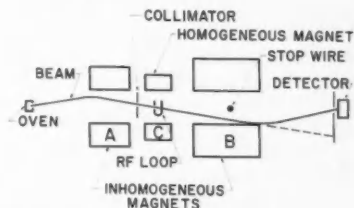
FIGURE 2. *Schematic arrangement of an atomic beam apparatus.*

data is, in general, sufficient to allow a unique assignment of ground state electronic configurations. The atomic beam technique is adaptable to the use of trace quantities of radioactive materials and thus offers promise for the determination of the electronic structures of all the transuranium elements.

Berkelium and Californium

Very recently S. G. Thompson and B. B. Cunningham succeeded in isolating berkelium (atomic number 97) and californium (atomic number 98)

3

in macroscopic or weighable amounts for the first time. In April of last year (1958) these investigators isolated 0.23 microgram of berkelium (as Bk^{249}) which had been formed as a result of the irradiation of about 8 grams of Pu^{239} and its transmutation products with neutrons for approximately five years in the Materials Testing Reactor (MTR) at Arco, Idaho. The first macroscopic quantity of californium isolated was obtained in July of last year and consisted of 0.06 microgram of a mixture of the isotopes Cf^{249}, Cf^{250}, Cf^{251}, and Cf^{252} which had been prepared by the same method as the berkelium.

With these materials, Thompson and Cunningham measured the magnetic susceptibilities of the tripositive ions of berkelium and californium over the temperature range 77 to 298°K. The data obtained for californium (and gadolinium for purpose of comparison) are shown in Figure 3. The results obtained in both inves-

FIGURE 4. *The magnetic moments of actinide and lanthanide elements.*

tigations agree very well with those expected for berkelium and californium as may be seen from Figure 4. In this figure are plotted the magnetic moments, determined by experiment and by theory, for a number of actinide elements. The data are consistent only with the filling of the "5f" electronic shell in the actinide elements. A plot of the magnetic moments of the lanthanide elements falls almost exactly on the theoretical curve shown.

The absorption spectra of the ions Bk^{+3} and Cf^{+3} in aqueous solution have been studied also. Visual observation failed to reveal absorption for either ion in the region from about 4600 to 7400 A, but a photographic method has shown that broad and quite faint absorption bands occur in californium around 7800 and 8300 A. The absorption spectrum of Cf^{+3} (and dysprosium for purpose of comparison) in dilute hydrochloric acid solution is represented in Figure 5. Rough estimates indicate that the absorption intensities are much weaker than those observed in the lighter actinides, and, in fact, have intensities
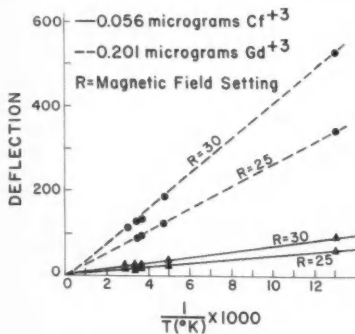
FIGURE 3. *Magnetic susceptibilities of the tripositive ions of berkelium and californium in the temperature range 77 to 298° K.*
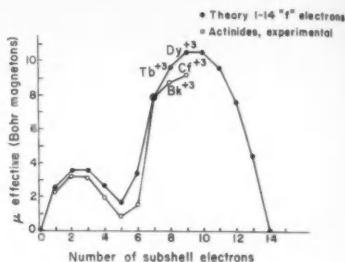
comparable to those found typically in lanthanide ions. This indicates that as the 5f electron shell becomes more deeply embedded in the second half

FIGURE 5. *The solution absorption spectrum of Cf*$^{+3}$. *The wave-length range between the dotted lines was explored.*

of the actinide series the elements begin to resemble the lanthanide elements even more.

A reduction in absorption intensity with increased ion charge has been noticed in the lighter actinides by Jorgensen. This would appear to be related to the effect mentioned, since in each case the diminished intensity is associated with an increase in effective nuclear charge.

Einsteinium and Fermium

Although it is not of very recent occurrence it seems worthwhile to review the discoveries of the next two transplutonium elements, einsteinium (atomic number 99) and fermium (atomic number 100) in view of the possible utility of their method of production for the future synthesis of new isotopes and elements. The discoveries of these two elements were unexpected by-products of the first test thermonuclear explosion to be produced. Einsteinium and fermium

were discovered because routine chemical identifications of fallout substances were made in connection with such tests in order to establish the properties of the explosion.
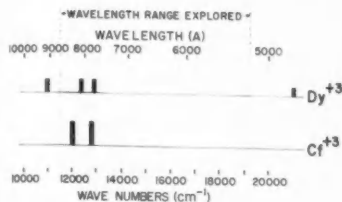
Heavy isotopes such as the previously unknown Pu^{244} and Pu^{246} were detected in the initial investigation of the debris and their presence suggested that very heavy uranium isotopes had been formed in the explosion by the irradiation of the uranium in the device by the extremely high neutron flux that existed for microseconds. The neutrons were captured within this very small fraction of a second and since beta decay will not, in general, proceed with a half life shorter than about 0.1 second, there was no opportunity for beta decay to occur during the synthesis. The subsequent beta decay of the heavy uranium isotopes led to the nuclides found in the explosion debris. In Figure 6 we can see the reaction paths by which these heavy elements were formed. Thus, for example, the production of Fm^{255} was via the synthesis of U^{255} by neutron capture in U^{238} followed by a long chain of
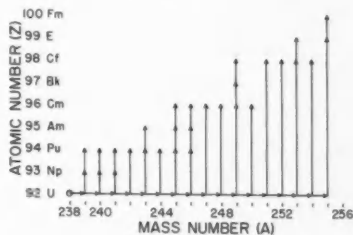

FIGURE 6. *Nuclear reactions for the production of elements 99 and 100 in the first test thermonuclear explosion, November 1, 1952.*

short-lived beta decays, U^{255} $\beta^- \rightarrow$ Np^{255} $\beta^- \rightarrow Pu^{255}$ $\beta^- \rightarrow \ldots \ldots$ Fm^{255}, all of which occur after the neutron capture reactions are completed. Figure 7 shows the relative yields of heavy nuclides obtained in this first explosion.
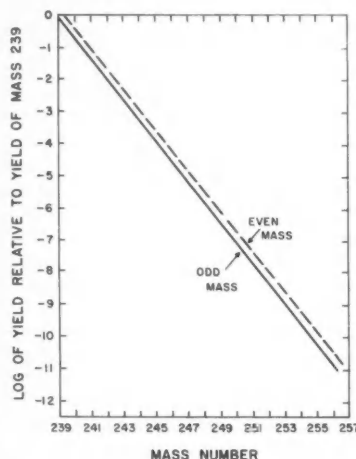

FIGURE 7. *Relative yields of heavy nuclides obtained in the first test thermonuclear explosion.*

Thermonuclear explosions offer a good method of producing new heavy isotopes of all the elements and possibly even new elements if the products can be recovered in better yield than has yet been possible. This method of synthesis of elements is similar to that which occurs in some stars. A particularly intriguing idea is the suggestion by the group of astrophysicists at the California Institute of Technology that a main source of energy for certain types of super-novae comes from the isotope Cf^{254}.

Einsteinium is the only transuranium element capable of isolation, but not yet isolated in macroscopic quantity (through its 280-day isotope E^{254} or its 20-day isotope E^{253}), and it seems likely that this will be accomplished within the next year or two, the material to be prepared through the neutron irradiation of elements of high atomic number for a prolonged period. Isotopes of trans-einsteinium elements are expected to have half lives too short to permit their isolation in weighable amount by traditional methods, although new techniques permitting special measurements are possible.

Mendelevium

Two isotopes of mendelevium (element 101) are now known, both being prepared by helium-ion bombardments of einsteinium in the form of the isotope E^{253}. It is not presently feasible to synthesize mendelevium, or any other transfermium element, by slow neutron irradiation of elements of high atomic number because some of the intermediate isotopes which must capture neutrons have half lives too short to allow their presence in appreciable concentration as required.

In the experiments that resulted in the first detection of a mendelevium isotope, a new technique was developed that was later applied in work leading to the discovery of element 102 and presumably will be used in the further discoveries of new elements. In view of this, I shall briefly discuss the discovery of mendelevium.

The synthesis of element 101 was planned and accomplished with a target consisting of only about 10^9 atoms of einsteinium as E^{253} which had

been prepared by the neutron irradiation of plutonium (as illustrated below in Fig. 20). Up to this time, no one had attempted the detection of transmutation products produced by the charged particle bombardment of invisible amounts of material and 10^9 atoms is invisible by many orders of magnitude! Calculations indicated that on the basis of the estimated cross section for the reaction only one atom of element 101 per experiment could be expected. The approximate number of atoms of element 101, N, expected in a bombardment was calculated as follows: $N \cong N'\sigma It$. N' is the number of einsteinium atoms used as a target; σ, the cross section for the reaction which was predicted to be about 10^{-27} square centimeters on the basis of the known value for previously observed similar reactions; I, the intensity of the helium ion beam which was about 10^{14} particles per second per square centimeter; and t, the predicted half life for the isotopes expected, which was of the order of 10^4 seconds. Using these numbers and some arithmetic we can see that the preparation of only about one atom per experiment could be expected! $[(10^9)(10^{-27})(10^{14})(10^4) =$ one atom per experiment.] Element 101 was, however, successfully produced and identified in spite of the fact that the prediction of a yield of one atom per experiment was correct.

Adding to the complexity of the experiment was the necessity for the separation of the one atom of element 101 from the target material and its chemical identification as a homologue of the rare earth thulium by the ion-exchange method. The analogy between the ion-exchange behavior of corresponding actinide and lanthanide elements has been the key to the discovery of most of the transuranium elements. Their first known isotopes are available in exceedingly small amounts and may have very short existences; in addition, the transplutonium elements have a very close chemical resemblance. The ion exchange adsorption and elution technique, in contrast to most conventional chemical separation methods, has the necessary selectivity and rapidity in accomplishing the chemical identification of such elements. A preliminary separation of the atoms of element 101 from the einsteinium was accomplished by

RECOILING PRODUCT
CATCHER FOIL
ION BEAM
TARGET
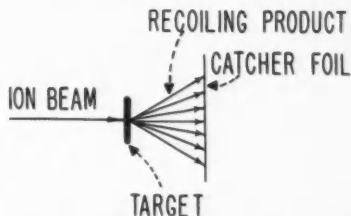
FIGURE 8. *Schematic drawing showing the recoil technique.*

a new method, the recoil technique. This technique is illustrated in Figure 8. The target was prepared by plating the einsteinium as a very thin layer onto a gold foil. The foil was bombarded by a beam of helium ions sent through the back of the foil so that the atoms of element 101, recoiling due to the momentum of the projectiles, could be caught on a second gold foil, the "catcher" foil. This second foil was dissolved and the chemical separations performed. The chemical identification was accomplished in an ion-exchange experiment involving the combined products from three successive bombardments in which a

total of five spontaneous fission counts and hence five atoms was observed in the element 101 elution position. Figure 9 shows the elution data obtained.
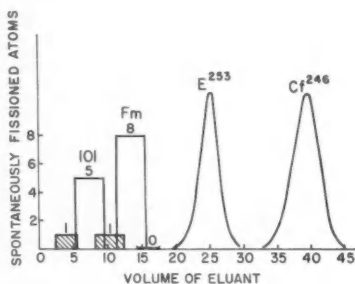
FIGURE 9. *Elution data obtained during the experiments which resulted in the discovery of element 101. Dowex-50 ion-exchange resin was used and the eluant was ammonium a-hydroxyisobutyrate.*

The activity of the E^{253} and Cf^{246}, present as tracers for calibration purposes, is due to alpha particles. The first mendelevium isotope discovered has the mass number 256 and decays by electron capture with a half life of about an hour to Fm^{256} which is responsible for the spontaneous fission decay. The fact that the radioactive decay involved the spontaneous fission process was a fortunate circumstance. This mode of decay has a high, almost 100 percent, detection efficiency and zero background.

Later confirmatory experiments using larger amounts of target E^{253} have led to the production of hundreds of atoms of mendelevium per experiment.

Figure 10 summarizes the steps in the discovery of mendelevium and was reproduced from an interesting review of the mendelevium experiment which was published in the Soviet journal *"Priroda."* In this figure (1) represents the helium ion beam; (2), the target; (3), the "catcher" foil; (4), the dissolving of the catcher foil; (5), the ion exchange column showing the relative order of elution of elements 99, 100, and 101; and (6) and (7), the instruments for detection of the spontaneous fission involved in the decay of the mendelevium.
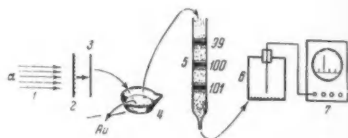
FIGURE 10. *Summary of the steps in the discovery of mendelevium* (reproduced from Priroda *44* (November), 83(1955)).

Recently a second isotope of mendelevium, with the mass number 255, has been prepared and identified by a group at the University of California Radiation Laboratory. It was prepared by the helium ion bombardment of E^{253} and was separated in much the same way as the first isotope of mendelevium to be discovered. The new isotope has a half life of about a half hour and decays by electron capture.

Element 102

In 1957 a team of scientists from Argonne National Laboratory in the United States, the Atomic Energy Research Establishment in Harwell, England, and the Nobel Institute for

Physics in Stockholm, Sweden, announced the discovery of an isotope of element 102 as a result of research performed at the Nobel Institute. The isotope was reportedly produced by bombarding Cm^{244} with cyclotron-produced $C^{13(+4)}$ ions and decayed by the emission of 8.5-Mev alpha particles with a half life of about 10 minutes. The name nobelium was suggested by this group for the element. Unfortunately, repeated experiments at the University of California Radiation Laboratory have failed to confirm this discovery.

In April of 1958, A. Ghiorso, T. Sikkeland, J. R. Walton, and myself identified the isotope 102^{254} as a product of the bombardment of Cm^{246} with C^{12} ions accelerated in the new heavy ion linear accelerator (HILAC) at Berkeley. The discovery was made possible by the use of a radically new method in which two physical separations were performed: first, the element 102 isotope was separated from the target material, and second, the atoms of the daughter element were separated from the parent element 102.

Figure 11 shows a schematic drawing of the experimental arrangement;
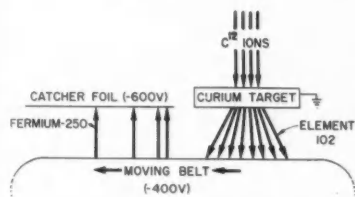
FIGURE 11. *Schematic drawing showing experimental arrangement used in the discovery of element 102.*

this is shown in more detail in Figure 12. The target consisted of curium deposited on a thin nickel foil, and it was enclosed in a container filled with helium gas. The curium was bombarded with C^{12} ions and the
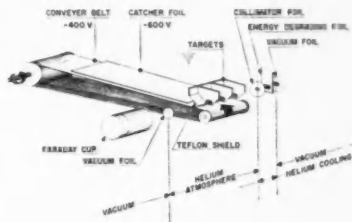
FIGURE 12. *Experimental arrangement used in the discovery of element 102.*

transmuted atoms were knocked into the helium gas to absorb their recoil energy. It was found that with a sufficient electric field strength practically all of these positively charged atoms could be attracted to a moving, negatively charged metallic belt, the "conveyor" belt placed directly beneath the target. The belt was then passed under a foil, the "catcher" foil, which was charged negatively relative to the belt. Approximately half of the element 102 atoms undergoing radioactive decay by alpha-particle emission would cause their daughter atoms to recoil from the surface of the belt to the catcher foil. The catcher foil was cut transversely to the direction of the belt motion into five equal length sections after a time of bombardment suited to the half life of the daughter atom to be examined, and each section was analyzed simultaneously in counters. It was possible to make all the desired measurements for identi-

fying the daughter Fm^{250} atoms deposited on the catcher foils and thus to determine the half life of the parent of the recoiling atoms. It was found that Fm^{250} could be collected on the catcher foils in accordance with a parent half life of 3 seconds. Changing the belt speed was found to change the distribution of the Fm^{250} on the catcher foil in a manner conforming to a three-second parent.

The Fm^{250} on the catcher foil was dissolved and separated from the other actinide elements present by the familiar ion exchange adsorption and elution method. It was identified by its elution in the well-known element 100 position. Figure 13 shows the elution curve obtained in an experiment
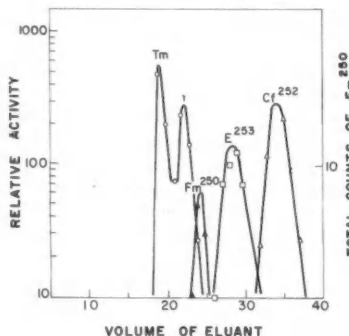
FIGURE 13. *Elution data obtained in the discovery experiments showing the Fm^{250} daughter of 102^{254}. The Tm, Y, E^{253}, and Cf^{252} activities were added as tracers for calibration purposes. Dowex-50 ion-exchange resin was used, and the eluant was ammonium a-hydroxyisobutyrate.*

where nine atoms of Fm^{250} were observed.

The investigators at the University of California have not yet made their suggestion for a name for element 102.

Since coming to this conference I have learned of the recent interesting experiments of G. N. Flerov and his group at the Atomic Energy Institute in Moscow. In experiments starting in 1957 and continuing up to the present they have produced an isotope, emitting 8.8 ± 0.5-Mev alpha particles, in the bombardment of Pu^{241} (and Pu^{242}) with high-energy O^{16} ions accelerated in their cyclotron. This product was separated from the target by the recoil technique and the energy of the alpha particles was measured by use of a photographic emulsion technique. No chemical identification was made. Their results are consistent with the half life observed by the California group, but not with that reported by the Stockholm - Harwell - Argonne group. It is quite possible that this alpha activity observed in the USSR is due at least in part to the isotope 102^{254} identified by the California group. It appears that the Moscow work complements the Berkeley work nicely, and it is hoped that we can proceed from here on in this field of investigation with close cooperation between the two laboratories.

Future Elements

The preparation and detection of new transuranium elements seems possible. Investigation of the known transuranium elements, which possess a total of about seven dozen isotopes, has led to a systematization of the

radioactive decay data in such a manner that the decay properties of undiscovered nuclides can, in general, be successfully predicted. The predominant mode of radioactive decay of the transuranium elements is by alpha particle emission, but decay by the spontaneous fission process becomes more and more important as the elements of highest atomic number are approached. In fact, for some isotopes this latter mode of decay begins to proceed at a rate comparable to decay by alpha-particle emission by the time element 100 is reached. The regularities for both modes of decay have been found to be greatest for nuclei which contain an even number of neutrons and an even number of protons, thus making predictions of the properties for undiscovered isotopes of this type the most certain. For isotopes with an odd number of protons or an odd number of neutrons or an odd number of both protons and neutrons, the rate of decay by both alpha decay and by spontaneous fission is slower than for the even type. Figure 14 shows the predicted half lives (indicated by a broken line) of the longest-lived isotopes for elements up to element 110. Unless unexpected islands of stability due to closed neutron or proton shells are found, the predictions based on the regularities in the decay properties suggest that it should be possible to produce and detect not more than about six elements beyond the heaviest now known.

By the time elements 104 and 105 are reached, we shall probably find that the longest-lived isotopes that can be prepared will exist barely long enough for the performance of tradi-tional methods of chemical identification; this will undoubtedly be made on isotopes with an odd number of nucleons. The present criteria for the discovery of a new element, chemical identification by traditional methods and separation from all previously known elements, will probably have to be changed at some point. Careful investigations of decay properties and reaction yields and mechanisms, together with the use of the recoil technique combined in some cases with the chemical identification of daughter isotopes, should provide means for the satisfactory identification of isotopes with very short half lives. Decay properties may have to be measured at the target area, on recoil product nuclei, during the bombardment. In some cases, it may be possible to make a satisfactory identification of new element isotopes by using simple and fast methods involving the migration of gaseous atoms or ions, volatility properties, reactions with surfaces, or
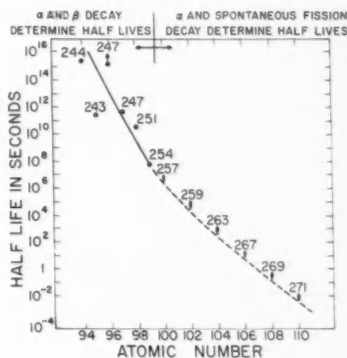

FIGURE 14. *Predicted half lives (indicated by broken line) of the longest-lived isotopes up to element 110.*

gas-flow reactions. It is likely that the identification of the first isotopes of all the new elements that will be discovered in the future will be accomplished by such methods, and the production of isotopes of these new elements with sufficiently long half lives to allow chemical identification by traditional methods will follow later if this is possible at all. Regardless of the method used, *evidence for the discovery of a new element should include a reasonable establishment of the atomic number, and this requires more than the observation of predicted decay properties and yields.* For example, the establishment of unique genetic relationship with a known lower element, such as was done for element 102, may be taken as the required additional information. We may find that it will eventually not be possible to satisfy these requirements when the preparation and detection of elements substantially farther up the atomic number scale is under investigation some years from now.

The chemical properties of the elements beyond element 102 can be estimated to the same extent that membership of any element in a certain group or column in the periodic table foretells its chemical properties. The position in the periodic table of undiscovered elements up to element 118 can be predicted as a consequence of having determined the point of filling of the 5f electron shell which occurs at element 103, although many of these elements will never be synthesized. It is expected that the actinide series will be completed at element 103 and that elements 104, 105, 106, etc., will be fitted in under haf--

nium, tantalum, tungsten, etc., including the positions occupied by thorium, protactinium, and uranium in the pre-World War II periodic table. The filling of the 6d electron shell should be followed by the addition of electrons to the 7p shell, with the rare-gas structure being attained at element 118.

It seems probable that the chemical identification of element 103 and of isotopes of element 102 with sufficiently long half lives will be made by the ion-exchange method which provides
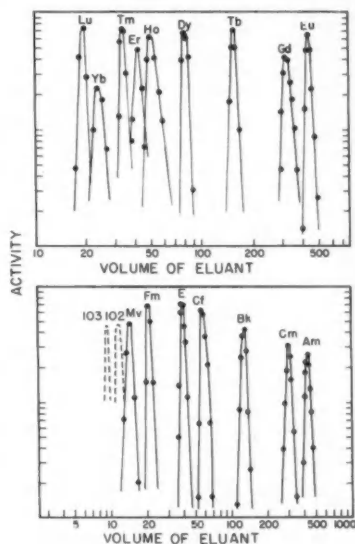

FIGURE 15. *Elution position of tripositive lanthanide and actinide ions using Dowex-50 ion-exchange resin with ammonium a-hydroxyisobutyrate as the eluant. The positions predicted for elements 102 and 103 are indicated by dotted lines.*

12

the necessary selectivity and rapidity. Figure 15 shows the elution position predicted for these two elements together with data obtained in experiments with other actinide and homologous lanthanide elements. Element 102 might be expected to have, in addition to a stable III oxidation state, a somewhat unstable II state in aqueous solution. The lower oxidation state may prove to be important in the eventual chemical identification of longer-lived isotopes of element 102. If the stability of this II state is comparable to the stability of the II state of ytterbium, then a rapid separation of this element from the other actinide elements may be effected through electrolytic or amalgam reduction, using ytterbium as a carrier. It is expected that the metallic form of element 102 will have a low density and a high volatility relative to the preceding actinide elements.

Element 104 should be exclusively tetrapositive in aqueous solution and should resemble its homologues hafnium and zirconium. Element 104 would be expected to have a soluble fluoride which will permit its separation from other actinide elements by precipitating the insoluble fluorides of the tripositive actinides, leaving ele-

FIGURE 17. *Target area of heavy-ion linear accelerator (HILAC) at the University of California Radiation Laboratory in Berkeley, California.*

ment 104 in solution. Solvent extraction may also prove to be a rapid and effective method of separating element 104 from the heavier tripositive actinide elements.

Element 105 should resemble niobium and tantalum and in some respects protactinium, with the V oxidation state expected to be the most important. Although it is not a true chemical homologue of protactinium, element 105 might resemble protactinium in its carrying and solvent extraction properties. The chemical properties of element 106 can be deduced from those of tungsten and molybdenum. Thus we might expect to find the III, IV, V, and VI oxidation states. Elements 107, 108, 109, 110, etc., would be expected to have chemical properties similar to those of rhenium, osmium, iridium, platinum, etc., respectively, although isotopes sufficiently long-lived to permit study of their chemical properties may not exist.
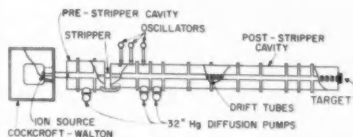
I shall consider next the methods

FIGURE 16. *Line drawing of the heavy-ion linear accelerator (HILAC) at the University of California Radiation Laboratory in Berkeley, California.*
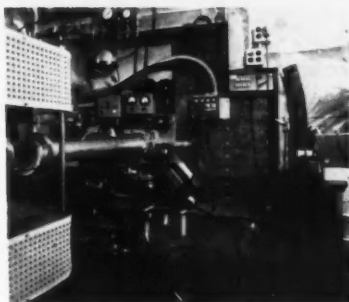
by which these undiscovered elements might be prepared. The method of multiple slow neutron capture as a result of intense neutron irradiation of elements of high atomic number over a long period of time has little utility in the first synthesis of transfermium elements. The production of new transuranium isotopes and elements in thermonuclear explosions, under proper auspices, of course, offers good possibilities as I mentioned earlier. Synthesis by heavy-ion bombardment offers promise for the production of elements of high atomic number. Isotopes of californium, einsteinium, and fermium have been produced by the bombardment of uranium with carbon, nitrogen, and oxygen ions, respectively, and element 102 was discovered as a product of the bombardment of curium with carbon ions. These heavy ions can be accelerated in cyclotrons of the conventional type but specially designed cyclotrons and linear accelerators which will be devoted to the acceleration of

FIGURE 18. *View showing the vacuum tank of the heavy-ion linear accelerator (HILAC) at the University of California Radiation Laboratory in Berkeley, California.*

heavy ions to energies sufficient to transmute the heaviest nuclei are also coming into operation in several laboratories throughout the world. (The new cyclotron in Moscow is designed to produce large beams of heavy ions, including magnesium and aluminum ions, at a mass to charge ratio of about ten.) Figure 16 shows a line drawing of the heavy-ion linear ac-

FIGURE 19. *View showing the diffusion pump section of the heavy-ion linear accelerator (HILAC) at the University of California Radiation Laboratory in Berkeley, California.*

celerator (HILAC) at the University of California Radiation Laboratory in Berkeley, and Figures 17, 18, and 19 show pictures of this machine. Even with the use of heavy ions, the reaction yields are small due to the competition of the fission reaction. This competition is the more severe the higher the atomic number and the heavier the projectile; the heavier projectile requires more energy to surmount the potential barrier, and this gives more excitation energy to the nucleus which leads to more steps of competition with fission as successive neutrons are emitted.

The lack of availability of target materials of high atomic number pre-
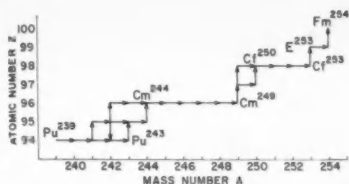
FIGURE 20. *Nuclear reactions for the production of heavy isotopes by intense slow neutron irradiation.*

FIGURE 21. *Production of heavy nuclides by the irradiation of Pu^{239} at a flux of 3×10^{14} neutrons per square centimeter per second.*

sents a serious problem. Figure 20 shows the reaction paths for the preparation of transplutonium elements by slow neutron irradiation of Pu^{239}, and in Figure 21, an indication of the time required for the preparation of Cm^{248}, Cf^{252}, and E^{254} is given. It can be seen that starting with one kilogram of Pu^{239} it would take approximately five to ten years to produce about one milligram of Cf^{252} at a neutron flux of 3×10^{14} neutrons per square centimeter per second. In the United States we have a program under way for the production of milligram amounts of berkelium and californium and microgram amounts of einsteinium, which, unless a higher-flux reactor is built, will employ a neutron flux of 3×10^{14} in the later stages. According to present plans we would obtain about one milligram of Cf^{252} in about ten years' time. In

order to prepare milligram amounts of berkelium and californium and microgram amounts of einsteinium for target materials on a more reasonable time scale, new, expensive, high-flux reactors producing 10^{15} to 10^{16} neutrons per square centimeter per second are needed.

In conclusion, it appears that we can look forward to the addition of new elements to the periodic table as a continuing result of modern-day alchemy. The transuranium elements will thus continue to add much to our knowledge of atomic and nuclear structure.

On the Back Cover

▶ THE CONCEPT *that the heaviest elements are actinides has led to their placement in the periodic table shown on the back cover. The positions which thorium, protactinium, and uranium have vacated, namely, the eka-hafnium, eka-tantalum, and eka-tungsten positions, will presumably be taken by the elements with atomic* numbers *104, 105, and 106 when these are discovered.*

Dr. Seaborg makes these predictions in his recent book, "The Transuranium Elements," published by Yale University Press on September 17, 1958 ($7.00), which also includes the history and development of plutonium during World War II.

Chemical Products from Britain

by TOM MARGERISON
Scientific Editor of "The New Scientist" (London)

➤ BRITAIN HAS HELD a distinguished place in chemical manufacture since the beginning of the industrial revolution. The names of many of the 19th century industrial chemists — Musgrave, Roebuck, Perkin, Gastner, Peter Spence, Brunner, Mond — are still familiar.

In some branches of the industry, particularly those dealing with "heavy" chemicals — sulphuric acid, caustic soda and so forth — Britain has remained through the years in a leading position. In other branches she quickly lost her lead.

A United States Development

For example, oil is a much more flexible starting point for carbon-containing chemicals than coal, and the large oil refining industry in the United States led to the rapid development of the petroleum chemicals industry.

Britain has no indigenous oil, and it was not until after the end of the 1939-45 war that the decision was made to build major oil refineries in Britain, and to import crude oil instead of refined petroleum products.

Large new refineries came into operation at Stanlow, in the English county of Cheshire, Fawley, on Southampton water, and along the Thames Estuary and elsewhere, offering an abundant supply of raw chemicals, with the result that what was one of the weakest parts of Britain's chemical industry became among the most progressive.

New Chemical Plants

Development in this field is still very rapid, and many new chemical plants for the manufacture of plastics, synthetic rubber, man-made fibres such as "terylene" (manufactured in the United States as "dacron"), ingredients for paint, and starting substances for pharmaceutical and agricultural chemicals are under construction.

Many of these new products are rapidly becoming major exports. For example, since 1948 the export of petroleum products has risen from some £5,000,000 ($14,000,000) to about £91,000,000 ($254,800,000) per year, and the export of plastics has risen from £4,700,000 ($13,160,000) to £29,900,000 ($86,720,000) per year.

Developments in petrochemicals have been reflected by increased progress in every other branch of the chemical industry. For example, the manufacture of synthetic detergents has revolutionized the soap industry. Many different new materials have been produced and in the past few years the output of detergents has increased many times. About £8,000,000 ($22,400,000) worth of detergents are exported each year, nearly three times the quantity exported in 1953.

One major detergent manufacturing firm has found it worthwhile to construct its own sulphuric plant. The main reason for this is that a few years ago the whole of that section of the chemical industry based upon sulphur as a raw material was badly

threatened by the sudden reduction of supplies of raw sulphur from the United States.

Expansion in Gasoline Additives

Another part of the chemical industry which has benefited greatly from expansion of petroleum-refining capacity is the making of gasoline additives. The exports of tetraethyl-lead compounds and other "anti-knock" additives have increased five times in quantity since 1953 and now stand at about £12,000,000 ($33,600,000) a year.

The process by which tetraethyl-lead compounds are made includes the extraction of the element bromine from the sea. A plant has been built at Amlwch in the island of Anglesey, off the coast of Wales, which treats very large quantities of sea water to
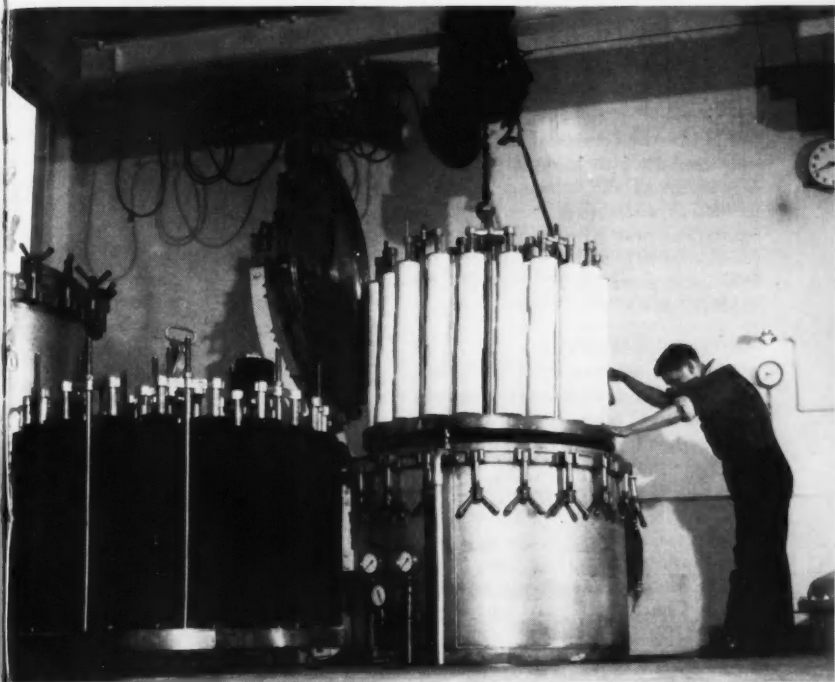
➤ SPHERICAL TANKS are for storing liquid under pressure at the Stanlow oil refinery of the Shell Petroleum Company, Ltd., near Ellesmere Port, in the English county of Cheshire. Chemicals produced by Britain's oil refining industry are used in the manufacture of plastics, acetate rayon, insecticides, paints, detergents and many other products.

extract the bromine. This particular site was chosen because tidal currents are strong and a fresh supply of sea water is continually carried past the works.

Synthetic Rubber Industry

Mention must also be made of the synthetic rubber industry which is growing quickly in Britain.

A number of the large rubber companies have grouped together to build a large synthetic rubber plant close to Fawley refinery, for the production of S-type rubber (a general purpose synthetic rubber) which has come into production in the past few months.

The British chemical industry is now one of the most rapidly developing sectors of the economy. In 1954 its total expenditure on new plant and equipment was about £95,000,000 ($266,000,000) and the figures for 1957 are expected to be £120,000,000 ($336,000,000).

Increasing Exports

Although the output of the chemical industry is mainly used to supply the needs of other industries, over £267,400,000 ($748,720,000) worth of chemicals were exported during 1957.

Many of these exports came into the class of new products, such as sulphonamides, vitamins, anti-biotics, anti-histaminics and barbiturates.

Australia is the largest purchaser of Britain's chemical exports and in 1957 bought £22,300,000 ($62,440,000) worth. India is normally the second largest consumer, and in 1957 bought £16,600,000 ($46,480,000) worth of chemicals; but the Union of South Africa has recently been catching up. In 1957, the Union bought £12,800,-000 ($35,840,000) worth, but figures for the first half of 1958 suggest that now it may be buying more than India and becoming Britain's second largest customer for chemicals.

The export contribution of the British chemical industry, however, cannot be assessed from these figures alone, because every export, whether it be margarine or gasoline, automobile or sewing machine, contains quite a large proportion of the chemical industry's products.

Calcium in Muscle Contraction

➤ CALCIUM apparently acts as an essential link between the electrical and mechanical steps in muscle contraction, a Canadian researcher has reported.

By soaking frog skeletal muscle in calcium-free solutions, contraction was "consistently inhibited," Dr. George B. Frank of the University of Manitoba's department of pharmacology and therapeutics said.

If the soaking continued as long as 12 minutes, muscle contraction induced by potassium ions was always completely eliminated.

Dr. Frank reported this in the British scientific journal *Nature* (Dec. 27).

These results support the theory that electrical events such as depolarization at the surface of heart and skeletal muscle fibers permits or promotes the entrance of calcium which then initiates the muscle contraction.

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Transpiration of Moisture by Plants

➤ IN THE EXPERIMENT herein described water vapour transpired by plants is used to initiate a chemical reaction of spectacular interest.

Two perfectly circular sheets of cellophane or thin glazed card boards (each 10 inches diameter) are folded in the shape of funnels just as filter papers are dealt with, the shape being sustained by means of pins. An intimate mixture of *dry* and fine aluminum dust (0.5 gram) and resublimed and *dry* iodine crystals (0.75 gram) is prepared in a *dry* mortar, and is divided into two piles of equal size on bits of *dry* cement asbestos sheets or writing slate or flat china ware (2 inches wide). A funnel is placed over each pile. A living and unwashed plant like geranium or balsam freshly cut above the roots is secured. Five to six leaves are held enclosed in one funnel with the stem passed through a small hole in its apex into a test tube of water clamped at a convenient angle. The funnels are held gently pressed downwards by the hands.

The water vapour from the leaves that accumulates inside the funnel in less than a minute's time causes one pile to emit a violet smoke and after a few moments to burn with a white flame. Before this combustion occurs the funnel is taken away to exhibit the reaction. The other pile remains inactive and serves as a control. It can also be ignited by adding just one drop of water to it, showing that water initiates the chemical change.

If desired, a third pile of the mixture may be similarly set up at the beginning itself, but left untreated with water to show that no visible change takes place in the absence of readily available moisture. One may count the time loudly from the moment moisture is introduced up to the moment the fire begins.

In the interaction of aluminum and iodine, which results in the formation of aluminumiodide (AlI_3), water vapour functions as a catalyst. Hence all materials including the mortar should be thoroughly *dry* before use, and the mixture should be prepared just before the experiment, if the demonstration is to succeed. A few grams of resublimed iodine may be *dried* for three or four days over lumps of quick lime (calcium oxide) in a test-tube closed with a rubber stopper, the lime and the iodine being separated by a plug of asbestos fibres or glass wool. It is best to *dry* the aluminum dust at 110°C for an hour in an air oven or over a drying cone and store it like iodine.

When preserved *dry* in this manner, the chemicals are found ready at hand when an experiment is planned. With transparent funnels like cellophane, the behavior of the piles can be observed from the beginning. Glass funnels (5 inches diameter) are also serviceable. The stem of one should be cut off to admit the plant. A rainy or very humid weather is not suitable for the experiment.

A record of a motion picture film

of the demonstration prepared under a dry weather, will then be serviceable.

Using the chemicals in the restricted quantities mentioned, the experiment can be very safely performed. The demonstration is much more quickly accomplished, and is more spectacular than the usual one in which dehydrated cobalt chloride paper is used.

Nuclear Magnetic Resonance

➤ THE RATHER RECENT development of nuclear magnetic resonance spectroscopy (NMR) offers high promise for our understanding of the structures and motions of polymer molecules.

The familiar properties of high polymers depend greatly upon the structures and motions of the macromolecules. Often these molecular details are little understood, but their interest and importance are undeniable. In his technical report, "Study of high polymers by nuclear magnetic resonance," W. P. Slichter of Bell Telephone Laboratories outlines the most recent developments in this exciting field.

Mr. Slichter introduces the method by giving some of the disadvantages to other methods, including X-ray diffraction, measurements of dielectric and dynamic mechanical absorption, and infrared spectroscopy. Each method, he says, has important limitations.

For example, X-ray diffraction is ineffective in establishing the positions of hydrogen atoms, yet hydrogen is one of the most common constituents of polymer molecules. The study of molecular motion by the measurement of dielectric loss depends upon the existence of permanent electric dipoles in the substance. Yet many important polymers, such as rubber, polyethylene, polytetrafluoroethylene, and polystyrene, possess no electric dipoles if the molecules are pure. Other polymers contain electric dipoles dispersed by nonpolar segments, so that characterization of the motion of the dipoles does not necessarily describe the motion of the molecule as a whole. The polyamides and polyesters are examples of such molecules.

There are important limitations to NMR, too, Mr. Slichter says, but fortunately they differ from the restrictions of the other techniques. This method is often highly effective in establishing positions of hydrogen atoms, and is often able to examine motion in molecules which elude the dielectric method of measurement.

Magnetic Properties of Nuclei

Mr. Slichter goes on to explain the magnetic properties of nuclei, useful in the NMR method.

In addition to the fundamental properties of mass and charge, the nuclei of many isotopes possess angular momentum (spin). As in the case of the electron, this angular momentum is accompanied by a magnetic moment. That is, the nuclei of these isotopes behave as if they were rotating electric charges or current loops, giving rise to magnetic moments.

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cleus is very small compared with that of the electron. The evidences of nuclear magnetism appear in rather special though important ways, as in the hyperfine structure of atomic and molecular spectra.

Crystalline Polymers

Although no synthetic polymer is wholly crystalline, Mr. Slichter continues, the crystalline content of many polymers is high enough that one may be rather definite about the molecular configuration. X-ray diffraction studies have described the crystalline structures of a number of polymers in great detail. NMR studies promise to add to the X-ray information, particularly in fixing proton coordinates, and have already been valuable in describing molecular motion.

X-ray diffraction is still considered valuable, however, in the study of high polymers, and many companies are spending vast sums of money in this research. (Page 12 of CHEMISTRY, December, 1958.)

In conclusion, Mr. Slichter states that although nuclear magnetic resonance spectroscopy is a comparatively new field, it has already contributed in important ways to our knowledge of molecular structure and motion in many substances, including some important groups of high polymers. In dealing with high polymers, NMR suffers from some of the same difficulties encountered by other methods of measurement, such as the difficulties ensuing from distribution of molecular weights and from the mesomorphic structures of many polymers.

There are a great many areas in which NMR may be expected to make important contributions to our understanding of polymers, but it would be well to point out that this approach is far from being self-sufficient; rather, the emphasis must be upon combining the NMR results with those from other methods.

Vegetation on Mars

▶ EVIDENCE of vegetation, and therefore at least one form of life, has been found on Mars.

Dr. William M. Sinton of Lowell Observatory, Flagstaff, Ariz., said he now had definite proof that organic molecules are present in the dark regions of Mars. He told the American Astronomical Society meeting in Gainesville, Florida, that absorption bands at three wavelengths confirmed the presence of organic molecules.

The spectra of Syrtis Major, Pandorae Fretum, Mare Sirenum and Mare Cimmerium, all dark areas, showed the absorption. The absorption was absent or weak in the bright regions surrounding Arabia and Amazonis, so-called desert regions.

Dr. Sinton tested for the presence of organic molecules, a test for plants, on Mars in 1956 and repeated the test this year, using improved equipment obtained with a grant from the National Science Foundation in conjunction with the 200-inch Hale telescope of Mt. Wilson and Palomar Observatories, Pasadena, Calif. The sensitivi-

ty was increased to approximately ten times that of the 1956 observations.

This improvement, together with the larger telescope, permitted study of different regions of Mars, Dr. Sinton reported.

The three absorption bands were found at 3.43, 3.56 and 3.67 microns for the dark regions of Mars. In terrestrial plants, absorption occurs mainly in two bands at approximately 3.41 and 3.51 microns.

Dr. Sinton said the third band found on Mars may indicate a significant difference in the type of molecules present. However, the closeness of the absorption bands to 3.5 microns indicates they are definitely due to organic molecules.

Dr. Sinton suggested that wherever the planet is dark, these bands occur, even in regions that have become dark during the history of observations of Mars. If this is true, Dr. Sinton said, then organic molecules are produced in localized regions in short spans of time.

"Growth of vegetation," Dr. Sinton concluded, "certainly seems the most logical explanation for the appearance of organic matter."

Previously, theories of life on Mars have been primarily founded on the fact that dark and light changes are observed on the planet. These are thought to be seasonal changes, deriving their contrasting tones from the recurrence of vegetation.

Key to Body's Chemical Energy

➤ A "PRECISE chemical mechanism" has been proposed as the key to how the living organism converts food to chemical energy.

It is the pyridine nucleotide cycle, Dr. Theodore I. Bieber of the University of Mississippi said in Washington.

The pyridine nucleotides, which are substances of widespread biological occurrence, apparently play a crucial role in the hydrogen transfer needed to make ATP, Dr. Bieber said.

It is the chemical energy of ATP, or adenosine triphosphate, that provides the living organism with the "ready cash" of energy needed to function properly, the chemist explained.

In the pyridine nucleotide cycle, ATP molecules are generated with

the movement of hydrogen atoms in the so-called respiratory chain. The nucleotides do not undergo any permanent changes in the cycle, but are regenerated thus providing a continuing source of ATP.

Considerable experimental evidence is presently available for the pyridine nucleotide cycle, Dr. Bieber told scientists at the American Association for the Advancement of Science meeting. Studies of the living cell indicate that the chemical processes occurring can be explained by this mechanism.

"If it should be definitely confirmed, Dr. Bieber concluded, "then a major biochemical mystery would be solved, and research for the conquest and prevention of the deteriorative diseases, such as cancer, could be conducted on a more rational basis and hence with greater confidence."

Opportunities in Biochemistry

by THE AMERICAN SOCIETY OF BIOLOGICAL CHEMISTS

▶ BIOCHEMISTRY may be defined as that branch of science which uses chemical methods to study the composition of biological materials and the mechanisms of biological processes. This definition does little, however, to give an impression of the scope of this field of science. A truer picture can be found in the answers to the questions "What do biochemists do?" and "How do they do it?"

What Do Biochemists Do?

We are all aware that an animal or plant must eat, drink, and breathe to live. Biochemists are concerned with the answers to such fundamental questions as: What specific materials must an animal eat? Why are these required? What happens to these materials — are they used as fuel or to build materials which the organism requires? If they are used as fuel, how are they burned? If they are used for synthetic purposes, how are the reactions carried out? How is the energy obtained from the oxidation of foodstuffs used by the organism to do physical work? How is the oxygen of inspired air used in biological oxidation processes? How is the carbon dioxide formed in these oxidations disposed of by the organism? In the case of plants the cardinal questions are: How is the radiant energy of sunlight converted into chemical energy? What is the first chemical compound formed in this conversion? How is this compound used to form the host of complex materials which constitute a plant? What are the spec-

ial functions of the myriads of organic compounds present in plants and not in animals?

Another large area of inquiry, comparative biochemistry, concerns itself with the problems of how different plants and animals carry out similar processes. While there is, in general, a remarkable similarity between the chemical activities of all cells, there are also, in the infinite variety of nature, striking differences among species and phyla. Equally exciting is the investigation of those problems related to the function of specific tissues and organs, e. g., what are the chemical events which make possible muscular contraction, nervous activity, manufacture of the complex materials of blood, formation of urine, etc.? And wherein are they altered in disease?

To the answers to these and many similar questions, only those trained in biochemistry may have access. Similarly only the biochemist can ever hope to comprehend the nature of reproduction in plants and animals and the molecular basis for genetics.

Armed with this information still other biochemists seek to provide us with agents to prevent and cure disease, to alleviate suffering, to feed and even to clothe us better.

How Do They Do It?

It is apparent that the answers to all these questions could be sought in many ways. One investigator may be primarily concerned with the quanti-

tative determination of biologically important compounds. Since these materials may be present in minute concentrations, this may involve very precise analytical chemistry. Alternately, if a compound occurs in small amounts, it must affect an organism even when it is very dilute. Consequently, it may be determined quantitatively by its influence on the growth rate of a yeast, a bacterium, a plant or an animal. Another biochemist may use all of the tools and techniques of organic chemistry to isolate and to determine the structure of biological materials. Still another worker may use highly developed physical equipment to study the physical chemistry of biological systems and materials or follow a radioactive substance through its complex fate in a biological system. In yet another laboratory the problem studied may require all of these techniques. Indeed, a distinguished investigator has said that, "A biochemist will do anything to find out what he wants to know." If well-known standard methods are not adequate for the investigation of the chemical properties of the most complex chemical factories known, living cells, then new methods and new techniques must be devised.

How and Where Are Biochemists Trained?

In keeping with the diverse interests and methods of various biochemists, there is no rigidly prescribed program of preparation for work in this field. Many well-known biochemists have been trained in quite different disciplines and have been led into biochemistry by their research interests after the completion of their formal training. Some were trained as organic chemists and a smaller group as physical chemists before becoming actively interested in biochemical investigation, while some have received the M.D. degree and others have been trained primarily in botany, zoology, bacteriology, and physiology. It would appear that the principal common background of biochemists is thorough training in the basic disciplines of chemistry. With respect to undergraduate training for a career in biochemistry a paraphrase of the advice of John J. Abel seems appropriate: "Study chemistry. . . . Try with all your power to master enough of this great science to start you on your career."

Thus, it would be well for the undergraduate student to have studied inorganic, organic, analytical and physical chemistry before entering upon the study of biochemistry, proper. In addition, mathematics, including the calculus, and at least a general course in physics are eminently desirable. The well-trained biochemist operates on a base supported by two bastions, the physical sciences (chemistry and physics) and the biological sciences. Those contemplating careers in biochemistry would do well to acquire this biological foundation, at least in part, during their undergraduate years.

Whatever the path by which one travels into biochemistry, one salient fact emerges — that a prerequisite for successful work in this field is graduate training in some field of biological or physical science. If it is assumed that the student has already determined that he wishes to become a biochemist, then, after college the ideal choice of a school for graduate work

in biochemistry would be one whose research activities parallel his own interests. In general this is not possible since students who have only a vague knowledge of the field have undeveloped interests and have no access to information concerning the type of work done at various institutions. Since this ideal solution to the problem of graduate training is seldom attained, in practice most students are stimulated and directed by the interests of the faculty of the school in which they pursue their studies until they are mature enough to establish their own fields of interest. This process is extended in many cases by a year or more of postdoctoral training in a different laboratory from that in which the doctoral work was done.

Where Do Biochemists Work?

Employment opportunities for biochemists vary with the interests and training of the individual. The following list of typical places of employment is intended to be representative rather than exhaustive:

1. Teaching and research in universities in their medical schools, chemistry departments, biology departments, or in departments of biochemistry in schools of agriculture.

2. In large hospitals or medical centers as clinical biochemists supervising the operation of clinical chemistry laboratories or engaging in research frequently but not invariably in biochemical aspects of disease.

3. In government laboratories, e. g., the Public Health Service, Department of Agriculture, Food and Drug Administration, Atomic Energy Commission, etc.

4. Performing research in one of the privately endowed research centers.

5. In industry: In the food and beverage industries working on such problems as the preparation and preservation of cereals, flour, prepared foods, beer, meat products, etc.

In the pharmaceutical industry where problems of discovery, development and production of drugs, antibiotics, hormones, vitamins, and the many special preparations used in medicine may be encountered.

Thus, the biochemist stands on the very frontier of man's ever expanding understanding of the biological world. In few other disciplines is the rate of discovery and application proceeding at so rapid a pace. Only the biochemist speaks the language in which these many tales are told and is prepared to act upon them.

Cloverleaf Cyclotron

➤ "MORE atom-smashing power in a smaller package."

That was how a new type of cyclotron to be built at the University of California at Los Angeles was described to some 700 physicists at the Pacific Coast winter meeting of the American Physical Society at UCLA.

Currently under construction at UCLA, the "spiral cloverleaf cyclotron" was designed and described by Profs. J. R. Richardson, Byron T. Wright, and Kenneth R. MacKenzie of the UCLA physics department.

The spiral cyclotron presents a promising new design for getting around

the voltage limitations of the conventional cyclotrons.

With the 49-inch spiral cyclotron, the UCLA physicists will be able to accelerate particles to 50,000,000 electron volts (MEV).

In contrast, the famous and larger 60-inch conventional cyclotron at the University of California at Berkeley operates at a maximum of 20,000,000 electron volts.

The key feature of the UCLA cyclotron is a spiral cloverleaf, shaped like a child's pinwheel, with each of its four magnetic iron shims weighing 50 pounds and with a radius of $20\frac{1}{2}$ inches.

The spiral ridge design will allow continuous acceleration of particles, in contrast to the bursts of acceleration in prsent syncro-cyclotrons.

Continuous acceleration is possible because the atomic particles are kept in orbit and in step at constant angular speed, so that the particles stay in step with the electric field that boosts their speed each time they make a cycle.

√ *Chemistry Quiz* √

Directions: Mark within the parentheses corresponding to the answer you think is *most nearly correct.* Answers are on page 28.

A. Which one of the following does *not* possess the same empirical formula as the others?
1. cellulose
2. dextrin
3. fructose
4. starch

B. Which one of these metals will burn in both oxygen and nitrogen?
1. columbium
2. platinum
3. tantalum
4. zirconium

C. A *Geissler tube* is a
1. device to determine water pressure at great depths
2. glass tube designed to show electrical glow discharges
3. piece of chemical apparatus used in titrations
4. U-shaped container for bacterial cultures

D. Freon gases contain
1. bromine, nitrogen, and carbon
2. chlorine, argon, and hydrogen
3. fluorine and silicon
4. fluorine, chlorine, and carbon

E. One compound in which the carbon and hydrogen are *not* connected by a covalent bond is
1. $CHCl_3$
2. C_2H_2
3. C_2H_5OH
4. H_2CO_3

F. Synthetic gasoline can be produced by synthesis from hydrogen and carbon monoxide in the presence of a catalyst by
1. alkylation
2. hydroforming
3. polymerization
4. the Fischer-Tropsch process

Alpha Chi Sigma Fraternity

▶ ALPHA CHI SIGMA, a professional chemical fraternity, is a non-profit organization incorporated under the laws of the State of Wisconsin where it was founded December 11, 1902, at the University of Wisconsin by nine chemistry students. It is a charter member of the Professional Interfraternity Conference and is affiliated with the American Association for the Advancement of Science, and the National Safety Council. It is organized in two Branches: Collegiate (47 chapters) and Professional (30 alumni chapters in various industrial centers). Currently, 28,793 have been initiated into the fraternity. It is an organization for men and its only restrictions to membership are a required number of chemistry courses, a stipulated level of scholarship, a signed statement of intent by the proposed member to make chemistry his profession, and acceptable gentlemanly attributes. Initiation is through collegiate chapters only.

The motivation in the beginning of Alpha Chi Sigma by its nine young founders was a desire to know each other and their faculty better, thus substantiating the realization, either knowingly or unknowingly, that a knowledge of men, and an ability to associate with men, is as important a factor in success as a well-ordered fund of chemistry "know-how".

The Fraternity's purposes are built around the fact just stated and attempt to teach the invaluable essence of fraternalism as represented by association with one another, group living and management, respect for fellowman never learned as well as

through intimacy, and the give and take of valuable friendship.

Out of these come all the things which Alpha Chi Sigma chapters do and which range all the way from sponsoring scholastic awards, up through open lectures, assisting chemistry and chemical engineering departments in their activities, and even once, the responsibility of a chemistry building dedication.

Nationally, the Collegiate Branch operates a National Safety Program and each collegiate chapter is affiliated with the National Safety Council as is the national body of Alpha Chi Sigma. The Program is concerned with safe practices in chemical laboratories. The national body of the Fraternity, called the Grand Chapter, has designed, published and sold at cost throughout industry and educational organizations over the world, thousands of posters concerned with safe laboratory practice.

As a national unit, the Professional Branch sponsors financially at the rate of $1000 yearly, the "Pure Chemistry Award" of the American Chemical Society. Award money is raised every three years through voluntary contributions by professional (alumni) members only. Alpha Chi Sigma has just entered its 19th year supporting this Award.

The Fraternity prints various Manuals of Procedure to aid its chapters; a Pledge Manual, a portion of which is devoted to the history of alchemy; a yearly "Proceedings"; and the national exoteric publication is "The Hexagon of Alpha Chi Sigma", which appears quarterly. Conventions are bi-

ennial and the voting members of the Grand Chapter are the 21 national officers and the duly accredited representatives of the collegiate and professional chapters. During the interval between conventions, the Fraternity is operated by a national board of four elected officers designated as president; first, second and third vice-presidents, the third vice-president being the national ritualist; and a permanent secretary who is a member of the Fraternity and appointed by the national board of officers.

National headquarters have been located since 1926 at the following address: 5503 East Washington St., Indianapolis 19, Ind.

No Need for Extra Vitamins

➤ Most PEOPLE can get enough vitamins from a proper diet. They do not need extra vitamin preparations, the council on foods and nutrition of the American Medical Association has stressed.

The council criticized some national surveys which indicate that some people suffer from vitamin deficiencies because they do not receive sufficient varieties of food.

Vitamin pills or other preparations are unnecessary for individuals who maintain a diet that meets the recommended dietary allowances developed by the food and nutrition board of the National Research Council, the AMA council stated in that organization's journal (Jan. 3).

In fact, an extra dose of vitamins A or D can cause serious harm, the council pointed out.

"Generalization of survey findings as a basis for vitamin supplementation of healthy individuals is not rational. The methodology employed in these surveys and the standards used for interpretation have varied consider-ably. It is necessary for the physician to evaluate each person individually, the council stated.

Vitamins are essential nutrients, and their usual source is food, the council pointed out. All of the nutrients essential to maintain health in the normal individual are supplied by an adequate diet.

The AMA council did agree, however, that there are some situations where vitamin supplementation is both necessary and desirable.

It may be useful during periods of illness or a deranged mode of life that may result in impairment of absorption of nutrients or deterioration of dietary quality. Some babies also need supplements, they pointed out.

In conclusion, the council stressed that public health will best be served by insistence on a factual basis for vitamin supplementation and therapy. It is sound judgment to emphasize repeatedly that properly selected diets are the primary basis for good nutrition.

√ Answers to CHEMISTRY QUIZ on page 26.
A-3; B-4; C-2; D-4; E-4; F-4. √

Organization of Liquid

➤ WE KNOW why a solid is a solid, and a gas is a gas. There are theories that account for them. In solids, the molecules are packed regularly; in gases, they move freely at random.

But why is a liquid a liquid? There is no satisfactory theory in terms of molecular structure which can tell us why.

Previous approaches have either treated a liquid as a solid with imperfections, or as a gas which is crowded up. Few have attempted to treat a liquid as a unique structure.

Now, Prof. J. D. Bernal, F.R.S., crystallographer and head of the physics department at Birkbeck College, University of London, has developed a theory stating that the secret of the structure of liquids is organized irregularity. The molecules are coherently packed, but without any regularity.

The great problem has been to demonstrate this in a physical model, and to explain this model in mathematical terms.

He has attempted to construct by hand, using table tennis balls or plasticine, a physical model of organized irregularity.

He has also had to develop his own statistical geometry to make this mathematical model. Mathematicians have been unable to provide him with any short-cut formulae.

The story really begins in a fog-bound Moscow airport in 1932. Prof. Bernal was stuck there with another British scientist, Dr. W. H. Fowler, son-in-law to Lord Rutherford.

"We had nothing else to talk about so we discussed water," Prof. Bernal explained. "It was then I first formulated a general theory of liquids in which I tried to explain the structure by the arrangement of molecules."

What he has done now is to examine more closely the "neighbor-relations" in irregular assemblies of molecules. He has had to find out what are the irregular arrangements of points in space that satisfy one condition, namely, that no points can be nearer than a specified distance.

His conclusion is that the basic property of a liquid, its fluidity, can be most readily understood in terms of the packing of irregular polyhedra, as in a foam.

Recent experiments have shown that at high pressures there is a perceptible interval marked by high specific heat that separates liquids from gases. Prof. Bernal interprets this as a change from a loose but coherent arrangemnt of molecules to an incoherent arrangement of clumps of molecules.

He contradicts the commonly accepted view that a gas and a liquid form a single fluid phase. They are distinct states of matter, although one may pass into the other without visible discontinuity.

Prof. Bernal believes this is probably a very general phenomenon applying not only to all liquids and gases, but also to all conditions of critical mixtures.

From this arises a number of considerations. For example, he predicts that although mercury is a good conductor at a certain temperature (the

hypercritical point) it would lose this property and become a good insulator.

If the picture he is showing proves to be closer to reality than the more formal ones of previous workers, then there will be practical applications in the fields of refrigeration, gas-liquid separation, and the flow of liquids.

Oxygen and Food for Future

➤ ALGAE that "turn out" more oxygen and increase 1,000-fold in one day even at temperatures as high as 100 degrees Fahrenheit hold two possible promises for man's future, Dr. Constantine Sorokin said in Washington.

With their more effective conversion of carbon dioxide into "organic products of great economic value" — low temperature algae increase only eight-fold in the same time period — we may actually see a revolution in agriculture, Dr. Sorokin told Science Service.

The protein in algae is the same, and as nutritious, as that in meat. In future years, Dr. Sorokin, who is at the University of Maryland, predicted, we may be growing algae for food instead of crops that have remained basically the same throughout man's history as a farmer. However, he said, the algae will probably be processed chemically before being used as a food.

While some nations do not have a food shortage now, the use of algae as a source of human food is currently being intensively studied in places, such as Israel and Japan, where farming land is scarce. With the problem of feeding a world population that appears to be growing explosively, Dr. Sorokin pointed out, even nations such as the United States with its food surplus may be interested in algae cultivation.

A second possible use for these fast-growing high temperature algae is as photosynthetic gas exchanger.

In closed spaces such as submarines, spaceships and dwellings which man will build on other planets, algae can maintain a proper balance between oxygen and carbon dioxide for indefinite periods of time as they carry out photosynthesis. In one hour, Dr. Sorokin said, one unit volume of high temperature algae produces 180 volumes of oxygen.

However, one unit volume of low-temperature algae evolves only 45 volumes of oxygen in one hour — one-fourth as much.

Dr. Sorokin, who presented a report on studies with the two groups of algae to a symposium on the physiology of algae at the American Association for the Advancement of Science, explained that the high-temperature strain eliminated expensive cooling devices usually needed to grow the algae. Such devices have been required in the past since the so-called low temperature algae prefer a temperature of 25 degrees centigrade and cannot grow when it gets above 29 or 30 degrees centigrade.

With further improvements in the technique of cultivation of high-temperature algae their productivity will undoubtedly be increased, Dr. Sorokin concluded. The studies reported involved response of the two algae strains to growth under varying light intensities.

30

High Pressure for Nitric Acid

➤ THE APPLICATION of nitric acid in the manufacture of explosives and of cellulose nitrate products, as well as its use in the preparation of many of the metallic nitrates, and in the manufacture of fertilizers and of a variety of dyes, drugs, and other organic chemicals, accounts for its great importance in the chemical industry.

The chief source of nitric acid today is from the oxidation of ammonia under high pressure, although about 8% of the total is still supplied by Chilean sodium nitrate. Yields of nitric acid from ammonia range from 91% to 93%, depending on temperature of cooling water available, and further concentration up to 98% or more as required for nitration processes may be achieved by a subsequent processing step.

Use of Catalysts

In the high pressure process, anhydrous liquid ammonia is vaporized, by means of steam, at a pressure of 150 to 200 psi. The ammonia gas is mixed with preheated compressed air, then passed over a platinum catalyst in a converter at approximately 100 psi, or pounds per square inch, where the following reaction takes place:

$$4NH_3 + 5O_2 = 4NO + 6H_2O$$

This catalytic reaction is highly exothermic, with the high temperatures generated in the converter necessitating water jacket cooling.

Secondary Oxidation

The hot gas emerging from the converter gives up some of its heat in exchange with the tail gases. It then flows through an air preheater where additional heat is removed.

Further cooling to a temperature of 75 degrees to 100 degrees F is then accomplished with water cooling.

The cooled gas, containing nitrogen oxides, then flows into and up through an absorber tower containing a number of water-cooled bubble cap trays. A secondary oxidation step takes place in the tower according to the reaction:

$$2NO + O_2 = 2NO_2$$
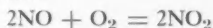
The nitric oxide thus produced reacts with steam condensate, introduced at the top of the tower, to produce nitric acid as follows:

$$3NO_2 + H_2O = 2HNO_3 + NO$$

The nitric acid produced in the absorber flows down over bleach trays, where nitrogen oxides are stripped from the acid by bleaching air introduced at the base of the column. The 55% to 60% acid thus produced is sent to storage or further processing steps.

Economical Measures

The tail gas from the nitric acid absorber, consisting largely of nitrogen, and traces of nitrogen oxides, passes through the tail gas preheater, is reduced in pressure by means of an expansion turbine, which drives a centrifugal air compressor, and is discharged to the atmosphere. Raising the temperature of the tail gas in the preheater permits recovery of additional power. By burning fuel gas in a chamber in the tail gas line prior to the expansion turbine, still further power savings may be made to reduce or eliminate entirely the steam or electric power requirement.

Air for the process is primarily sup-

plied by a motor or steam driven, centrifugal compressor.

The expansion turbine may contribute up to 60% of the power requirements, or more if auxiliary fuel is burned in the hot gas system ahead of the turbine.

If desired, a waste heat boiler is installed to produce high pressure steam amounting to 1400 to 1500 pounds per ton of nitric acid with a corresponding reduction in power recovered from the hot gases.

Lead Oxide, Potash and Sand

➤ BLOWING GLASS is akin to magic; it is both incredibly simple and incredibly difficult.

The tools have not changed much since the Middle Ages when the Murano glass blowers on an island near Venice held a near-monopoly of glass-making, being forbidden to leave their work under penalty of death but in recompense being granted the prized right to marry into the nobility. At that time their tools were a blowing pipe or iron, an iron punting rod, shears, a crude caliper, two or three slats of cherry wood to smooth or shape flat surfaces, and wooden pincers for opening or shaping glassware or hollow-ware. Though improved, the tools are much the same today.

The process, explained in the current issue of France Actuelle, begins with a "gatherer" who, at the end of a blowpipe, takes from the "pot" the exact amount for the piece to be made. He hands it to the "marver," who blows it into rough shape. A punting rod, with a blob of molten glass at its end, is then stuck to the free end of the piece being blown. This in turn is cracked off the blowpipe with a drop of cold water and a sudden jerk. The punting rod and its glass end are then turned over to the "gaffer," the finishing artist of the team who, with shears and slats, trims the piece, opens its mouth, and shapes

it to perfection, maintaining a constant rolling motion.

Finally, the finished article, cracked off the punting rod, is picked up in a wooden "fork" by a "boy" who takes it to a "lehr" or annealing oven where it is allowed to cool off gradually over a period of eight to twelve hours.

True crystal, manufactured by only a few firms in Europe and America, contains anywhere from 26 percent to 30 percent lead oxide, plus about 50 percent sand which must be absolutely free of impurities. (The sand used by the French firm *Baccarat* comes from the forest of Fontainebleau, and is snow-white and fine as face powder.) Potash and a few other ingredients complete the "batch," together with a portion of "cullet," or broken glass from defectives and rejects. The more of the latter used, it so happens, the better the quality of the crystal. Crystal has more sparkle and brilliance than ordinary glass, is heavier, softer, and more durable.

Items in current production include every type of glass in every color for every drink and every occasion, decanters, pitchers, finger bowls, dessert or salad plates, cocktail mixers, candelabra, chandeliers, and all kinds of crystal lighting equipment and accessories, paperweights (cameos), and decorative sculptures.

Zinc

by BURTON L. HAWK

➤ ZINC HAS at least one distinction: it begins with the last letter of the alphabet. This is a decided advantage to Scrabble fans and others who are interested in word games. Another advantage: it is easy to locate in an index.

Early Beginning

No one knows who first discovered zinc. Articles made of the metal have been found which have existed long before the Christian era. Before zinc was known to be an element it was used extensively in brass, which is an alloy of copper and zinc. It was not recognized definitely as an element until the seventeenth century. Today it is used chiefly in galvanizing. This process consists of coating iron with a layer of zinc by electroplating, dipping the iron in molten zinc, or by spraying the iron with melted zinc. Thus applied, the zinc prevents corrosion of the iron and it resists corrosion itself because of a firmly attached layer of basic zinc carbonate which is formed. This coating prevents further action of the metal with oxygen. Another important use of zinc is as an electrode in batteries and dry cells. And, of course, it is used in huge quantities in that oldest of all alloys: brass.

For laboratory work, zinc is made available in the popular granulated or "mossy" form. This form is made by pouring melted zinc slowly into water. It is a hard, brittle metal which becomes somewhat malleable when heated to 125-deg. and then becomes more brittle when heated above 200-deg. Try to bend a piece of mossy zinc with a pliers and note how easily it breaks. Now heat a piece of the metal in a flame until it is quite hot. Drop it on a hard surface and tap it lightly with a hammer. It will shatter into many small fragments, like a piece of glass.

Zinc melts at 419 degrees. If you have access to a hot gas flame, you should be able to melt some of the metal. Then you can prepare your own mossy zinc by pouring the molten metal into a large container of water.

Zinc reacts with the oxygen of the air to form zinc oxide. Heat several small pieces of the metal over a hot flame. As the metal begins to melt, stir gently with a metal rod. Note that a yellow powdery material forms on the surface. This is zinc oxide which is yellow when hot but will turn white when cool.

Zinc Dust

Another popular type of zinc used in the laboratory is the powdered form commonly known as zinc dust. Zinc burns in the air with a bluish white flame. This can be demonstrated by using the powdered form. Sprinkle a "pinch" of zinc powder into a flame. It will flare up in a brilliant flash. The result of this is the formation of zinc oxide, as we prepared above from the solid metal.

Of course, zinc is more reactive in the powdered state. To demonstrate

the rapid and fiery oxidation, ignited by water, proceed as follows. Mix together thoroughly 10 parts of ammonium nitrate with one part of ammonium chloride. Spread the mixture out in a thin layer in the bottom of a metal pan or jar lid. Cover the entire mixture with a thin layer of powdered zinc. Now, to ignite the reaction allow a few drops of water to fall on the mixture. Stand back. The mixture will smolder, smoke and finally burst into a brilliant flame. This experiment was always a favorite of ours and it never fails to impress an audience. The fact that a dry mixture is set afire with water consistently baffles the uninitiated. And, incidentally, it baffles us too. How does it work?

Zinc and Sulfur

Another spectacular display is the reaction between zinc and sulfur. These two elements insist on showing off their union with a brilliant pyrotechnical performance. Mix together two parts of zinc with one part of sulfur. Form the mixture in a small pile in the center of a large metal pan. Place the pan where no danger will be done by flying sparks. Using a tongs or pliers carefully ignite the pile with touch paper. Be sure to keep your distance. The reaction is violent and sudden. The mixture flares up instantly in a brilliant whitish-blue flame. *Use small quantities!* The touch paper, used as a fuse, is prepared by soaking filter paper in a concentrated solution of potassium nitrate, allowing to dry and then cutting into thin strips.

Zinc is quite active and will displace many metals from solution. For example, drop a piece of zinc into copper sulfate solution. After a short while, examine the metal and you see deposits of copper. Or, for a more spectacular demonstration, prepare a solution of lead acetate and acidify it by adding a few drops of acetic acid. Suspend a strip of zinc in this solution. The metallic lead will separate out and form beautiful crystalline spangles on the strip of zinc.

Zinc and Electricity

Finally, suppose we demonstrate the role that zinc plays in the generation of electricity. Most dry cells and small flashlight batteries contain zinc and carbon as electrodes immersed in a dry electrolyte. We will duplicate this reaction by using a liquid electrolyte instead. Place a very dilute solution of sulfuric acid in a beaker. Immerse a carbon rod in the solution on one side of the container and a strip of zinc on the other side. Do not allow the two materials to touch each other. These are our two electrodes and the carbon is equivalent to the center post or "positive" connection of a dry cell and the zinc is the outer post or "negative" connection.

To generate electricity, simply close the circuit by connecting a thin copper wire from the carbon to the zinc. If you have a sensitive voltmeter, connect the positive lead to the carbon and the negative lead to the zinc. Look for a slight deflection of the needle which indicates a flow of electricity.

So much for the metal zinc. However, this element forms many useful compounds also, and we will investigate these at another time.
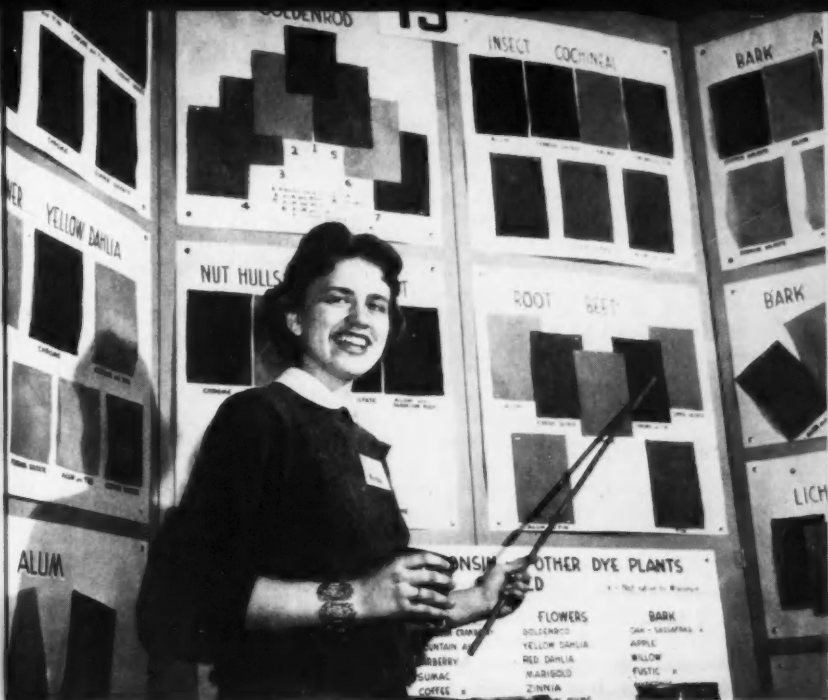
➤ Jane Ruth Karau, 17, of 510 West 6th St., Marshfield, Wis., is shown with her science display, her feature for the seventeenth annual Science Talent Institute. This display and project concerns her own methods for producing more than 500 dyes and the 250 samples of cloth which she colored with these dyes.

Natural Dyes for Home Use

by Jane Ruth Karau

➤ The use of natural dyes is not new, but recent trends toward crafts and weaving are reviving an interest in them. This study was undertaken in order to investigate the colors possible for home dyeing from plant material found in Wisconsin and of some not native to the state.

My project includes 250 dyed samples of cloth: woolen, silk, cotton, linen, and some synthetics and blends, whose colors were all obtained with the use of:

1. 50 dye materials, plant and animal — 43 grown in Wisconsin and 7 not found in the state,
2. 5 mordants
3. 1 zinc vat for indigo dyeing

Because most industrial processes are based on very large lots of cloth

and home economics investigations usually on per pound of cloth dyed, I had to reduce the dyeing recipes I needed for samples of cloth about 5 x 7 inches. This fortunately reduced the quantity of needed flower petals and other dye material to one pint and the resulting dye bath to approximately one quart. As a consequence also, this simplified my equipment, making it possible for me to run three to six tests at the same time with a double boiler arrangement I devised for this purpose.

Variety of Mordants

The dyeing process I followed can be divided into two parts: the mordanting procedure and the dyeing step itself.

Mordanting is carried out according to the cloth in question because the structure of cloth fibers differ. Wool and silk have the property of holding chemicals in their fibers, such as chromium oxide with which the dye stuff then combines to make a permanent color. Cotton and linen on the other hand do not absorb the metallic mordants as readily. I learned, however, that they will do so if an agent for fixing metallic mordants is used, such as tannic acid. By using different mordants with the dye material a variety of shades and sometimes even different colors are obtained from the same dye. Yellow dahlia, for example, used with chrome mordant produced a deep orange red, but a bright yellow with alum mordant.

For wool I used 5 mordants: alum (potassium aluminum sulfate), chrome (potassium dichromate), tin (stannous chloride), copper (cupric sul-

fate), and iron(ferrous sulfate). In some tests I also included what is known as tin brightening, a finishing step in which stannous chloride is added to either chrome or alum treated cloth when dyed. Whenever copper or iron mordants were used, a saddening effect was the significant result. However, in spite of its saddening effect copper sulfate produced a very acceptable variety of greens.

Nearly all dye tests with silk and the synthetics and blends shown in this report were made with alum, chrome or tin mordants. Except for tin, the procedures for mordanting these fabrics were the same as for wool, that is, fixing the cloth with potassium dichromate for chrome mordanting and with potassium aluminum sulfate and potassium bitartrate for the alum procedure. Because tin mordant hardens silk, steeping of silk for 15 minutes replaced the usual 30 minute light boil used for wool in tin mordanting, and from the observations I made with silk, it is fair to conclude that tin is by far the best mordant for it.

Time Procedure

Usually mordanting processes recommend boiling the cloth for one hour followed by overnight standing in the mordant in order to set the mordanting salt into the cloth fibers sufficiently to form the necessary color lakes with the dye extract. I used this method for alum and chrome mordanting, but with tin, iron and copper mordants better results were obtained with half-hour boiling time followed immediately by the dyeing step. Alum-tannin-alum mordanting used on cotton and linen, however,

required three days because overnight fixing time was allowed after each step, i. e., boiling with alum, then tannic acid and again with alum.

For the actual dyeing step the dye solutions were prepared directly from the flower petals or other dye materials using hot water extraction. In most cases the extraction was extended to 30 minutes, but for nut hulls, sumac, cochineal and barks an overnight soaking preceded the extraction.

Materials Used

Both fresh and dried plant material was used. However, I discovered in the course of my work, that time could be saved if the dye extracts were made in larger quantities and refrigerated until needed. In this way they kept for as long as four weeks. Some attempt was made with the study of the pH value of the dyes and the color they produce. No definite conclusions could be drawn from the number of readings made. Although there appeared to be a recurrence of reds at the lower pH range, while the yellows and tans appeared most frequently between pH 3.5 - 6.5; readings beyond pH 6.5 were insufficient to make substantial comparisons.

I used three methods of dyeing:

1. The sample was mordanted first and then dyed in a separate dye bath.

2. The mordant and dye were in the same bath.

3. The sample was dyed first and the color fixed afterwards, referred to as the "stuffing process," used especially for copper and ferrous sulfates.

Regardless of the method used, the dyeing step was essentially the same: the cloth to be dyed was entered into a warm dye solution and then brought up to a gentle boil and continued for half an hour.

For certain dyes a mordant is not necessary. This is true of the three substantive dyes I used from lichens, fungus and the zinc vat for indigo dyeing. With the first two the dyeing is direct, but with the zinc vat the color is obtained through an intermediate reaction since the principle of the zinc vat depends on the property of the zinc dust in it to react with the slaked lime to form calcium zincate and hydrogen. The hydrogen thus liberated reduces the indigo to indigowhite which dissolves in the excess lime present. Cloth dipped into this liquid turns blue on exposure to air due to oxidation.

My vat was a glass jar large enough to hold two quarts of vat mixture. I found one particular advantage in the glass vessel. In the first place, I could see the chemical action when the hydrogen was liberated, and secondly, I was better able to remove the needed amber liquid from the vat before inserting into it the cloth sample for dyeing. In all tests made, shades of blue were varied by controlling the dilution in the vat. The same holds true for the indigo extract made with sulfuric acid.

Any Part of Plant

Top dyeing with the aid of the zinc vat was another method I used for varying colors, especially the greens. It was also used to superimpose darker colors other than indigo on colors that were not too pronounced.

Considering the 250 dyed samples, there is every evidence that almost any part of a plant can be used for dyeing purposes. Sometimes the same

color can be obtained from two or more parts of the plant as was obtained with willow bark and willow leaves. Likewise, similar parts of two different plants may yield the same or very nearly the same colors. A typical instance is that of willow and apple bark.

A dye from the same plant may produce the same color on different fabrics, however, exceptions to this also occur. A solution to these differences may rest in the study of the pH of each dye.

Although I have made an extensive study of dye colors possible from natural dyes, there are many possibilities still open to the home-dyer or one engaged in occupational therapy if other plants, mordants or agents are used in various concentrations and with variations of temperature.

> "IF HE ASKS *whether you specialize in space medicine, say yes!*"

Fatty Acid Synthesis

► A MAJOR STEP forward in the research effort aimed at isolating cellular enzyme systems that direct and regulate the formation of fatty acids in the body has been made.

Biochemist Dr. Salih Wakil, on the staff of the University of Wisconsin's Institute in the department of Prof. David E. Green, reports in Journal of the American Chemical Society isolation of the first intermediate in the synthesis of long-chain fatty acids from acetic acid.

The intermediate is identified as malonic acid.

Not Reverse of Oxidation

Enzyme Institute scientists are convinced as a result of this step that fatty acid synthesis is not the reverse of fatty acid oxidation, the process by which these acids are burned up in the body.

Fatty acid metabolism has been a major research topic for 10 years at the Institute. Through step by step analysis it is hoped that each step in the conversion of foodstuffs to fatty acids may eventually be understood.

Last April, Wisconsin enzyme researchers announced discovery of a previously unknown enzyme system by which fatety acids are synthesized in the living organism. The organism's need for the vitamin biotin was partly explained by the discovery.

Biotin, most potent and ubiquitous known member of the vitamin B complex, was shown to be present as an essential part of the enzyme processes involved in synthesis of fatty acids.

A few years before the Institute had announced a series of steps by which fats are broken down by the enzyme systems in living cells. At that time it seemed probable that the activity of the same enzyme system could be reversed and that fatty acids could be synthesized from the organic compound known as acetyl co-enzyme A, the metabolically active form of acetic acid.

Continued investigation revealed an entirely different system. This is now believed to be the one employed most generally by the living organism in synthesizing fatty acids from acetyl co-enzyme A molecules.

The system studied was one conducting synthesis of palmitic acid, the main constituent of the fat in the fatty tissues of the animal body.

From the liver a highly purified enzyme system was isolated which catalyzes the synthesis of palmitic acid from acetyl co-enzyme A. Although biotin had long been known as one of the key substances required in nutrition, this was the first time it had been implicated directly in an enzymatic process, and in the formation of fatty acids.

Biotin-containing Enzyme

Recent discoveries at the Institute that both biotin and carbon dioxide are required for synthesis were clues that led to the isolation of malonic acid, and identification by Dr. Wakil.

He reported that "a biotin-containing enzyme is involved in the linking cf carbon dioxide to acetyl co-enzyme A with the formation of malonic

acid." As a result, "discovery of a completely novel and unexpected pathway for synthesis of fatty acids is now anticipated."

"The system of pigeon liver used in tests has its counterpart in animal tissues as well, and the pathway described for synthesis of long-chain fatty acids probably has universal application," reported Dr. Wakil.

New Energy Range for Cosmic Rays

➤ A NEW ENERGY range for studies of cosmic rays and the high energy particles produced in giant atom smashers has been opened by development of a specialized cloud chamber technique.

The new range is from 10 to 1,000 billion electron volts (Bev), the American Physical Society meeting in Los Angeles was told. Dr. William B. Fretter and Mrs. Luisa Hansen of the University of California, Berkeley, said the cloud chamber technique allowed physicists for the first time to differentiate between high energy nuclear particles traveling at energies above two Bev.

In conventional cloud chambers, bubble chambers and photoemulsions, particles above two Bev all look alike. In their cloud chamber, containing a mixture of argon and helium gas, Dr. Fretter and Mrs. Hansen can make distinctions up to 20 Bev. This permits them to figure out what happens in nuclear events with energies up to 1,000 Bev.

The achievement opens a new region of high energy physics for cosmic ray scientists, who have been hard pressed by big atom-smashers that produce high energy particles in greater quantity and under controlled conditions. Atom smashers, while they are supreme in energy ranges in which they operate, cannot match the energies of cosmic rays. Therefore, the technique enlarges the research potential of cosmic ray scientists.

At the same time, argon-helium chambers show promise of solving one of the big problems faced by scientists who are building giant atom smashers in the 25 Bev range at Brookhaven and in Geneva, Switzerland.

The Berkeley scientists appear to have taken a step in providing the means for analysis of the high energy particles to be produced by such machines.

In part, Dr. Fretter's technique derives from a theory about what happens to the electrical field of a particle when it gets to high energy.

At rest the electrical field is radial, extending in all directions at the same distance and with the same strength.

However, at great energy, the field in the direction the particle in traveling is blunted, almost disappearing; and at right angles to this direction, the field becomes stronger and extends farther with greater energy. This effect is relativistic, its occurrence being predicted by Einstein's theory of relativity.

By experimentation, Dr. Fretter found a combination of gases in which ionization would increase relativistically with increases in energy,

up to 20 Bev. A droplet count in a cosmic ray track can reveal the particle's energy.

Dr. Fretter said he can make the critical distinction between a pion and a proton up to 20 Bev. Some distinctions cannot be made, as between a K particle and a proton, but he expects sensitivity to increase.

With detailed information so far gathered — the first in this high-energy range—Dr. Fretter has shown that the late Enrico Fermi's theory of what happens in proton-proton collisions at these energies is not valid. The data are consistent with theories of both L. Landau, a Russian, and Werner Heisenberg, a German, and further work may show which is the most useful.

Cells May Be Aged by Enzymes

➤ EXPERIMENTS being conducted by an Ohio State University biochemist indicate that the manufacture of enzymes may cause cells to age.

The research project, now in its fifth year, is being directed by Dr. Joseph E. Varner, 37, (of 244 Royal Forest Blvd., Columbus) professor of biochemistry in the university's College of Agriculture and Home Economics.

Dr. Varner, who will go to Cambridge (England) University next September for a year as a National Science Foundation research fellow, is trying to find out what biochemical changes take place in aging cells.

Thus far, the Ohio state scientist has been using the cells of ordinary garden peas and tomatoes for his experiments because they provide a raw material easily obtained.

"Aging, or senescence, is a physiological process common to all cells — whether of plant, animal or bacterial origin," Dr. Varner said. "In the plant kingdom, the cells in ripening fruit, in mature leaves and in the storage tissue of germinating seeds undergo an easily recognizable period of senescence.

"However, the biochemical reactions in aging cells are not limited to

degradative processes," he continued. "The cells of an aging tomato, for example, are still producing useful energy (as high energy phosphate compounds) and are still performing biochemical work and biochemical syntheses."

Now conducting the research under a grant made available by the U. S. Public Health Service, Dr. Varner previously worked under a Rockefeller Foundation Grant. Assisting him were Dr. Joy D. Marks of Cincinnati, and Dr. J. Lowell Young, now assistant professor at Oregon State College, Corvallis, Ore.

The biochemist said that as a result of conclusions reached during studies conducted up to 1956, he now is proceeding on the theory that enzymes (agents which speed up chemical reactions in cells) associated with aging processes are manufactured in the cells immediately before senescence begins.

"Cells may age as a result of the synthesis of enzymes which specifically bring about those degradative changes which we recognize as characteristic of aging cells," the scientist said.

Peas, Dr. Varner's prime raw material, are soaked in water for 24

hours to touch off the sprouting process. After a sprout, which contains the tiny stem, root and leaves, reaches a certain stage of development, he removes the cotyledons (the meaty halves of the pea which supply raw material for seedlings) and grinds them up to obtain cells for study.

He then ruptures the cotyledon cells and extracts their components. These extracts then are assayed for several enzyme activities.

The biochemical changes taking place in the aging cotyledons are followed by observing the changing levels of these enzyme activities.

This process is carried out under various conditions and changes in temperature on cells ranging in age from one day to several weeks.

"From these studies it has been found that many of the biochemical changes characteristic of aging plant cells require energy, and that the cellular energy available is closely controlled by a hormone-like substance carried to the aging cells from other parts of the plant," Dr. Varner reported.

The Ohio State scientist's present studies are aimed at identifying this controlling substance and at understanding better the specific biochemical changes characteristic of aging cells.

Sorption of Mercury by Fungus Spores

➤ MERCURY, in combination with organic units like phenyl and pyridyl groups, is especially poisonous to many fungi, the agents of decay, and of many plant diseases as well.

If we understood better how the mercurials work on the fungus we would be able to exploit their potentialities and, perhaps, to devise even better inhibition chemicals.

Reporting the above at the December meeting of the American Association for the Advancement of Science, was Dr. John M. Leonard of the U. S. Naval Research Laboratory, Washington, D. C. He conducted this research in cooperation with Dr. Dorothea Klemme, also from the Research Laboratory.

The authors have endeavored to explore the very early stages of the poisoning process, the intake of organic mercurial by the fungus spore. Fungus spores were treated with mercurial compounds which contained a radioactive mercury isotope as a tracer. It was shown that the very high affinity of fungus tissue for mercury results in an enormous concentrating effect; thus a seemingly minuscule dose of "administered" poison becomes a rather high "received" dose. The increase may be of the order of several thousandfold.

The uptake of poison is a very fast process — within a few seconds the spores have bound tenaciously more mercurial than they could possibly hold as a simple surface layer. A system of rapid transit to the interior of the fungus is therefore indicated. Chemically speaking, there seem to be certain relatively specific "portals of entry." Some of these probably are reduced sulfide groups, but there are others which will be studied in the near future.

High Temperature Coating for MO

▶ To PROTECT molybdenum against high-temperature oxidation, the National Bureau of Standards, in research performed for the Navy Bureau of Aeronautics, has investigated a composite electrode-posited coating of nickel over chromium. This is reported in the *Technical News Bulletin,* (December), issued by the Bureau.

Although molybdenum has greater structural strength at high temperatures than steel, it has not, thus far, been used under such conditions because of its ease of oxidation. However, with the protective coating studied by D. E. Couch and associates, oxidation of molybdenum is prevented for over 1,000 hr at 980° C, and for over 300 hr at 1,100° C. The two-layer coating is therefore considered a promising material for use on turbine blades and similar high-temperature components.

A high-temperature coating for molybdenum must have a number of special properties. The coating must, of course, be oxidation-resistant, but it is equally essential that it be non-porous and ductile. Even minute imperfections can allow the molybdenum beneath the coating to oxidize and to disappear completely within a few hours. Studies of the chromium-nickel coating show that if properly applied, it satisfies these requirements.

The first step in the plating procedure is to etch the molybdenum with a 1:1 solution of concentrated sulfuric and phosphoric acids. A 1-mil chromium deposit is electroplated on the molybdenum at 85° C and 120 amp/-dm^2. Then the newly plated surface is again etched, this time with a 1:1 hydrochloric acid, given a nickel strike, and plated with 7 mils of nickel. For this purpose, nickel deposited from a Watts type bath at 2 to 5 amp/dm^2 is superior to that deposited from an all-chloride bath.

Durability Studies

Several types of durability experiments were conducted with the coated samples. To test the adhesion of the coating to the molybdenum, the completed specimens were bent until fractured. The break produced was usually within the molybdenum itself and not between the electrodeposited layers — showing excellent adhesion of the plating. To a large extent, the soundness of the deposit determines the effectiveness of the protection.

Specimens with the composite coating were exposed to air at 1,100° C until the coatings were perforated or until a white smoke of molybdic oxide appeared. At this temperature, the coating withstood oxidation for an average of 300 hr; but at 1,200° C oxidation was greatly accelerated. Preheating of the samples in an inert atmosphere decreased the oxidation life of the coatings.

Types of Defects

In metallurgical examinations of a series of the coated specimens which had been subjected to different periods of air oxidation at 1,100° C, three underlying causes of failure were noted: Subsurface oxidation; grain-boundary oxidation; and edge separation.

The subsurface oxide is due to reaction with atmospheric oxygen and

not with oxygen trapped in the coating. This explanation is plausible because the oxide was not observed in samples heated in a helium atmosphere. Apparently the subsurface oxide layer is caused by diffusion of the atmospheric oxygen which passes through the nickel coating and reacts with the nickel-chromium alloy underneath. Further support of this explanation is the fact that the low-chromium alloy is more easily oxidized than is pure nickel. The subsurface oxide forms through much thicker layers of nickel over a curved surface than over a flat surface.

The boundaries of the metal crystals are more vulnerable to oxygen attack. Hence, as its name implies, grain-boundary oxidation directly follows the boundary of the grains.

Edge separation occurs within the chromium-nickel diffusion layer when a sample is alternately heated and cooled several times. This type of defect, which is being further investigated, actually produces a gap within the layers.

To observe more closely the effect of molybdenum diffusing through the coating, a study was also made of interdiffusion of the three metals — molybdenum, chromium, and nickel. For this experiment, a bar of molybdenum was plated with 2 mils of chromium and 14 mils of nickel, and then heated in hydrogen. After 600 hr, 1 to 2 percent of the molybdenum had diffused to the surface. Although this metal could be detected through 10 mils of nickel, no structural changes were noted. Apparently small amounts of the molybdenum which have diffused into the surface do not appreciably affect the grain structure of the chromium-nickel alloy coating.

In further investigations of the three types of defects, electroformed nickel instead of molybdenum was coated with chromium and nickel and then oxidized. Upon examination, the same three formations — subsurface oxide, grain oxidation, and edge separation — which had occurred with the coated molybdenum — were noted. Thus, molybdenum itself is not directly involved in these major sources of failure.

Public is Assured of Safe Food Supply

➤ THE PUBLIC has every reason to be assured of an adequate and safe food supply under existing laws regulating chemical additives to foods, declared Doctor David B. Hand, head of the Department of Food Science and Technology at Cornell's New York State Experiment Station at Geneva.

"Our farmers and food processors lead the world in the use of modern methods, ranging from production to packaging," Doctor Hand said in an article on "Chemical Food Additives"

in the Station's quarterly, "Farm Research."

"Our laws now cover all possibilities of contamination and adulteration and make mandatory the practice of pretesting that was already an established practice by the great majority of food processors," he continued.

Chemicals used in food production can be grouped in two general classes, incidental and intentional food additives, explained the Station scientist.

Incidental additives include those things that are used in food production, such as fertilizers, pesticides, and herbicides, which are not intended to remain in the final food as consumed. Traces of incidental additives may remain in or on foods, but the quantity is kept so small that they do not create a health hazard.

Intentional additives include such things as coloring matter, flavoring compounds, vitamins and other nutrients, substances that improve the texture, consistency, or keeping quality of various foods, artificial sweetening agents, and so on.

A recent survey indicates that about 500 intentional additives are in use, with nearly 300 of these flavoring agents.

"Both agriculture and food technology have become chemical sciences," commented Doctor Hand, adding that, "If it were not for fertilizers, pesticides, and food additives, our store shelves would not be displaying the adequate quantities of high-quality foods they now carry."

Electrical Purifying Method

▶ A NEW WAY to purify substances is being studied by scientists at Princeton's plastics laboratory.

Herbert A. Pohl, head of the laboratory's dielectrics section, told the American Association for the Advancement of Science meeting, that liquids, powders, or mixtures of them can be pumped around, lifted, mixed, and even separated into their components by subjecting them to nonuniform electric fields.

Dr. Pohl said the method works at high efficiency, and that it offers new ways to grade and purify solids.

The method is based on theoretical knowledge that nonuniform electric fields exert a force upon neutral matter, pulling it to the region of highest field density. Experiments at Princeton showed particles of different sizes are pulled to the central electrode at different rates, and that particles of the same size are pulled at varying rates if they differ in electrical nature.

A "curious" phenomenon has been observed. As the voltage is increased the rate of pull-out of particles suspended in a liquid steadily increases. Then suddenly all pull-out stops; particles already pulled out fly off the electrode. This "critical voltage," Dr. Pohl said, is sharply dependent on the size and nature of the particles. This offers another possible way of grading and purifying solids in suspension.

Agent Absorbs Ultraviolet Rays

▶ A NEW CHEMICAL makes possible plastic screens that stop invisible ultraviolet rays from natural or fluorescent light without stopping visible light rays.

The new chemical absorbs ultraviolet and transforms it into harmless radiation. Known as Cyasorb UV 24, it is being produced by American Cyanamid Company. It is expected to find wide application in agricultural sheeting, shower curtains, lacquers and varnishes, and safety-glass windows.

Computer Controls Chemical Plant

➤ A COMPUTER-CONTROLLED chemical plant, believed by its developers to be the first such plant to use an electronic computer for the direct, on-line control of the over-all process, will be put in operation some time in 1959.

Installation will be the result of a joint study by the Monsanto Chemical Company in St. Louis, and Thompson-Ramo-Wooldridge, Inc., Los Angeles.

Monsanto expects to achieve maximum productivity from its plant investment at minimum operating cost by having the computer continually monitor the process conditions, make calculations and automatically adjust the controls for best results.

Synthetic Quartz Can End Import Dependence

➤ THIS COUNTRY's dependence on Brazil as a supplier of natural quartz may soon be at an end.

Large-scale domestic production of synthetic quartz by a process known as hydrothermal crystallization is now possible.

These views were expressed at the annual meeting of the American Institute of Chemical Engineers by R. A. Laudise of Bell Telephone Laboratories, Inc., Murray Hill, N. J., and R. A. Sullivan of Western Electric Company, Merrimack Valley Works, North Andover, Mass.

Quartz crystal is an essential component of long-distance communications equipment. Natural crystals of a size and quality suitable for communications use are found mainly in Brazil, where it is mined by individuals. Lately, the Brazilian supply has become unstable "due to the apparent depletion of larger stones."

Hydrothermal crystallization, according to the two engineers, is the use of an aqueous solvent under high temperature and high pressure to increase the solubility of a material ordinarily hard to dissolve to a point where it can be crystallized on a seed crystal at an appreciable rate.

They reported that synthetic stones produced in a pilot plant were of excellent quality and that initial estimates of the process' feasibility appeared to have been conservative.

Prepackaged Rocket Engine Fired

➤ A PREPACKAGED liquid rocket engine, combining advantages of the liquid bi-propellant rocket engine with the safety and easy handling characteristics of solid propellants, has been successfully fired at the Naval Missile Test Center in California. This was revealed by Reaction Motors Division of Thiokol Chemical Corporation, which developed the engine for the Navy. Ready for immediate operation, the power plant can be stored at launching sites for indefinite periods. The normally complicated pre-firing preparation of liquid propellants is eliminated.

Book Condensations

FREE RADICALS: As Studied by Electron Spin Resonance — D. J. E. Ingram—*Academic*, 274 p., illus., $9.50. Introductory text explains basic theory, experimental methods, advantages and limitations of the technique and summarizes relevant work published.

CATALYSIS, Vol. VI: Alkylation, Isomerization, Polymerization, Cracking and Hydroreforming — Paul H. Emmett, Ed. — *Reinhold*, 706 p., illus., $19.50. Comprehensive treatment of hydrocarbon catalysis and catalytic processing.

VACUUM METALLURGY — Rointan F. Bunshah, Ed. — *Reinhold*, 272 p., illus., $12.50. Up-to-date reference work for engineers and research workers.

THE PHYSICS OF RUBBER ELASTICITY — L. R. G. Treloar — *Oxford Univ. Press*, 2nd ed., 242 p., $5.60. Special chapters on swelling phenomena and the estimation of the degree of cross-linking.

CHEMICAL CALCULATIONS—Bernard Jaffe — *World Bk.*, 3rd ed., 180 p., $2.20. Systematic presentation of the solution of type problems in mathematical chemistry with 1000 chemical problems.

WHAT'S IN THE AIR?—Hazel Holly — *Public Affairs Committee*, Pamphlet No. 275, 20 p., illus., paper, 25¢. Issued on the occasion of the National Conference on Air Pollution of the Public Health Service in November 1958.

THE CHEMISTRY AND TECHNOLOGY OF LEATHER, Vol. II: Types of Tannages — Fred O'Flaherty, William T.

Roddy and Robert M. Lollar, Eds. — *Reinhold*, 554 p., illus., $16.50. Monograph on the chemistry, processing and mechanism of tannery.

CHEMICAL TRANSFORMATIONS BY MICROORGANISMS — Frank H. Stodola — *Wiley*, 134 p., $4.25. On the chemical composition of microorganisms,
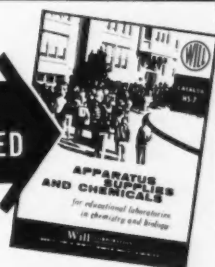
the organic type reactions they carry out and their synthetic powers.

ESSENTIAL FATTY ACIDS — H. M. Sinclair, Ed. — *Academic*, 268 p., illus., $9.50. Proceedings of the Fourth International Conference on Biochemical Problems of Lipids, Oxford 1957.

CHART OF RADIOISOTOPE APPLICATIONS — Howard F. Gunlock — *Nuclear-Chicago*, 23 x 36 inches, paper, $1, science teachers free upon request to publisher, 223 West Erie St., Chicago 10, Ill. Charts effects of radioisotope radiations on materials, effects of materials on radioisotopes, and tracing materials with radioisotopes.

ELECTROANALYTICAL CHEMISTRY — James J. Lingane — *Inter-science*, 2nd rev. ed., 669 p., illus., $14.50. New chapters on polarography, amperometry and chronopotentiometry.

OUTLINES OF ENZYME CHEMISTRY —J. B. Neilands and Paul K. Stumpf, with chapter on Synthesis of Enzymes by Roger Y. Stanier — *Wiley*, 2nd ed., 411 p., illus., $8.50. Stresses basic principles and lists important properties of more than 500 enzymes.

Chemistry and Dental Science

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Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0080																	2 **He** 4.003
3 **Li** 6.940	4 **Be** 9.013											5 **B** 10.82	6 **C** 12.011	7 **N** 14.008	8 **O** 16.000	9 **F** 19.00	10 **Ne** 20.183
11 **Na** 22.991	12 **Mg** 24.32											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.975	16 **S** 32.066	17 **Cl** 35.457	18 **A** 39.944
19 **K** 39.100	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.95	24 **Cr** 52.01	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.94	28 **Ni** 58.71	29 **Cu** 63.54	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.60	33 **As** 74.91	34 **Se** 78.96	35 **Br** 79.916	36 **Kr** 83.80
37 **Rb** 85.48	38 **Sr** 87.63	39 **Y** 88.92	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc**	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.4	47 **Ag** 107.880	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.70	51 **Sb** 121.76	52 **Te** 127.61	53 **I** 126.91	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.36	57-71 **La Series**	72 **Hf** 178.50	73 **Ta** 180.95	74 **W** 183.86	75 **Re** 186.22	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.09	79 **Au** 197.0	80 **Hg** 200.61	81 **Tl** 204.39	82 **Pb** 207.21	83 **Bi** 208.99	84 **Po**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra** 226.03	89-103 **Ac Series**	(104)	(105)	(106)	(107)	(108)										

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